Mobile Clinical Message Specification for Pre-hospital Services

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Abstract— **Mobile computing capabilities of modern mobile devices support clinical communication and provide access to medical records from any part of the world. Even when adequate infrastructure is available, the issue of how to consistently deliver clinical documents without error in a wireless environment is challenging. The reliability of the transmission of clinical data from a mobile client to an electronic health record data server is handled by the mobile applications to verify and validate the data items. This paper presents a HL7-CDA standard clinical message specification for mobile communication protocols to verify and validate the accuracy of the message delivery. The messages are validated by a wrapper mechanism using mobile agent technology. Test results are presented from a real-world 9-1-1 Emergency Medical Services pre-hospital service application.**

Index Terms— **Electronic health record, HL7-CDA standard, mobile applications, message specification, mobile agent wrapper.**

I. Introduction

Electronic health record (EHR) system is an information and communication technology (ICT) initiative in the healthcare sector for persistent storage and longitudinal sharing of medical records across multiple healthcare organizations within a community, a region, a state, or an entire country. Medical records generated at different clinical systems are transmitted to the EHR data server through a distributed organizational infrastructure. As a global initiative to standardize EHR communication system, Canada Health Info way [1] has developed an interoperable electronic health record info-structure (EHRi). This architecture recommends a standard clinical message specification based on the Canadian Privacy Act [2] of 1983 and the Healthcare Insurance Portability and Accountability Act of 1996 (HIPAA) [3] for medical record representation for clinical data exchange between heterogeneous clinical systems.

Existing clinical systems generate electronic medical records and transmit them to the centralized EHR system through a wired network like Ethernet and may use wireless local area network (WLAN) technologies such as IEEE 802.11 a/b/g/n networks at the point of service location. Recent advances in the cellular and wireless technologies with the availability of high data rates [4]-[7], facilitate implementation of mobile communication system for exchange of medical records. Modern handheld devices like PDA, smart phones and tablet PCs having adequate memory spaces, high-speed processors and efficient operating systems can support mobile data transmission from customized clinical systems. To improve reliability for clinical data transmission using wireless networks, a standard message specification based on TCP/IP protocol (which is a secured communication protocol) is required.

II. Need for Standard Mobile Message Specification

Clinical systems generate messages containing medical data based on the assumption that the data models of participating applications or systems are unknown. For transmission of documents like diet chart, discharge summary and medical bills, the data modeling methods like extended backus-naur form (EBNF), and bachmann diagrams are used for extraction of attributes and data elements for message generation [8]. These messages are highly variable in structure and content representation. During data transmission, the applications interpret these messages partially correct in order to perform system functionality. Variance in message structure introduces correlation errors between the communicating systems. Hence, to interpret messages consistently, an EHR compatible standard message structure is required.

The Canadian Institute of Health Information (CIHI) [9] has recommended using an internationally recognized set of data elements for clinical communication, to enhance compliance and eliminate inconsistency. Complex and critical documents like diagnosis reports, test results and signal measurements are transmitted using information exchange data models like study data tabulation model (SDTM), analysis data model (ADaM), standard for exchange of non-clinical data (SEND), operational data model (ODM), and case report tabulation data definition specification (CRT-DDS) models, recommended by the clinical data interchange standard consortium (CDISC) [10]. However, problems such as system-integration, maintenance and compatibility prevail in these approaches.

The Canadian Privacy Act of 1983 and the HIPAA have worked together over the past decade to establish a new enhanced standard for all kinds of clinical communication. The confidentiality and ethical requirements of these acts make it very difficult to finalize a message specification that acknowledges reliable delivery of medical records. The clinical messaging specifications from different standard organizations like HL7-CDA, EDIFACT, CEN ENV 13606,

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OpenEHR, and DICOM are recommended for clinical communication [11]-[13]. However, the acknowledgment message specification is set to default in most of these standards. The application developers have to explicitly apply an acknowledgment mechanism without prior knowledge on status of the message delivered to the clinical system, which is inefficient.

Currently, the HL7 specification is recognized as a messaging standard for clinical applications; hence, technical implementations of all EHR systems connected through EHRi use messages in HL7 standard [15]. However, they do not present a standard clinical message specification for mobile communication. In this paper, a compact version of HL7-CDA specification is applied to derive mobile clinical message specification.

III. Requirements of Clinical Message Specification

In general, a message specification consists of set of attributes and data elements that semantically meets the system requirements like confidentiality, privacy and accuracy. A specification for clinical messages must also meet the medical system requirements to tackle environment issues such as unpredictable diagnostics, geographical mobility and complex data processing issues. To define a standard specification for mobile clinical systems, there are three primary requirements: 1) a unique data identifier, 2) a compact message wrapper and 3) an acknowledge receipt.

The first requirement is to represent and extract clinical data accurately and semantically. Data extraction from a message is performed using different methods such as delimiters, markers, signals and characters. In standard specifications, a message consists of text identifiers to indicate a header section and a body section. The message header consists of metadata to define the context of the dataset and the body section consists of the payload (the dataset). For example, the HTTP [16] and the SOAP [17] messages represent large volume of data in a nested multi-level structure based on the application. In SIP [18], the body section consists of five simple elements of unlimited length for payload with the message size is restricted to a maximum of 2700 bytes. A HL7-CDA message consists of a large set of attributes representing header and structured body section. However, these attributes are verbose and lengthy for a mobile message. A simplification process that reduces the message specification to a compact message by preserving the semantic values of clinical data is required.

The second requirement is a message wrapper that protects the content during transmission in a wireless networks. A message wrapper is an object that acts as an interface between the caller and the wrapped message to assure compatible and reliable message delivery. The wrapper object captures all required low-level details of the EHR message to encapsulate its contents with adequate information to perform its function. Zhao et al [19] has applied field wrappers for mediator-based systems to capture geospatial information in mobile data gathering to provide thematic information for sampling and analysis. Sahuguet & Azavant [20] has used message wrappers generated using world wide web wrapper factory (W4F) for delivering web pages in a faster and easier way. These efforts on mediator-based systems have significantly specified the use of wrappers to deliver messages accurately.

The third requirement is to generate an acknowledgment receipt for each message delivery. This acknowledgment message has to be obtained after successful delivery to the EHR. Analysis of the header attributes shows the rigidness in each specification to support additional attributes for acknowledgment receipt and consistency check. For example, the compact ‘16baseint’ data type in SOAP header specification does not support acknowledgment and consistency checking [17]. The authorization mechanism implemented as part of the SIP message header assures ACK message deliverance without content details [18]. Similar mechanism is explicitly specified in the MIME header of the HTTP. In HL7-CDA message, a header attribute is set to refer the acknowledgment section of the message body. However, the message structure provided by these specifications is cumbersome and error-prone. Hence, an acknowledgment message with essential details on the status of the message delivered is required.

IV. Proposed Message Structure

The HL7-CDA message structure consists of a header with attributes for identification, prioritization and acknowledgment; and a body with clinical data represented in multiple levels as sequence of bytes. Such messages require heavy processes for data extraction and consume more bandwidth, which are time consuming and expensive. To solve this problem and to meet the requirements discussed in the previous section, two methods: content simplification and wrapper formalization are used.

A. Content Simplification

The HL7-CDA specification uses XML [11] to represent the structure of clinical documents that meets the EHRi requirements. Though XML generates effective messages, it is considered to be verbose and has significant processing needs that are too expensive for mobile applications. Hence, simplification is needed to this specification before adoption by a mobile middleware. The following procedural steps are used in simplification of HL7-CDA message:

i. Apply generic data type
ii. Use a universal clinical event set
iii. Classify the captured data
iv. Generate message template

i) Data Types

Typical clinical data are represented in common data representation (CDR) specification with different precisions. For example, the date of intervention can be represented as May 04, 2009 vs. 04-20-2009 vs. 20-04-2009 20:45:02. Though format differs, it is essential that the semantics of data elements remain constant. Based on the nature of clinical observation, the elements are broadly classified into four main data types: narrative textual data, numeric measurements, imaging and recorded signals [14]. Here, only the narrative textual data type and numerical data type are considered.

a. Narrative Textual Data Representation

Narrative textual data represents clinical data like: admission notes, progress notes, discharge summaries, nursing notes, radiology reports, pathology reports and other clinical reports that are an integral part of a health record. During a clinical observation, a detailed description of the observations written in natural language, usually in English, along with technical terms related to specific interventions. Idioms, shorthand notes and phrases are used to enter the complaints. In the HL7-CDA document, the narrative text is represented as unstructured blogs or structured markup tags in the body section. In the message template, the narrative text is displayed using the <text> tag within a <section>.

In HL7-CDA template, the textual description are represented in both ASCII and non-ASCII characters. For example, the intervention details such as food taken before the incident, allergies and medications are written in narrative text by the paramedics.

b. Numerical Data Representation

Numerical measurements such as blood pressure (systolic and diastolic values), blood glucose level, body temperature, respiration rate, oxygen saturation and medication measurements are recorded in a report as integer or real numbers. The measuring unit of the medications and other procedures are represented as string characters. The clinical observations containing numerical values are represented in the message template using the <value> tag. The type of value and its size is defined using the HL7 data types. The <value> tag appears in the <observation> sub-section of the <section>. The complex values are represented as nested elements within the <observation>. The message consolidates data from a clinical source based on the clinical event.

ii) Universal Event Set

An event can be defined as a significant change in state of environment. The events are generally represented by the type of event, the timestamp and a set of related parameters. Depending on the type of event, the timestamp may be a single value or an interval. Parameters may be an individual value or reference to an older value. In clinical systems, the messages represent real world events. These events must be delivered to the related event consumer through appropriate messaging service. The messaging service can be a service that tightly couples the sender and the receiver for interaction or a service that decouples the two end systems and provides routing of message from the source to the sink.

In general, events can be of three types: simple events, composite events and derived events. Simple events are temporary events without any major consequence. Composite events are aggregation of events. Composite events are derived from event representations and the operators of event algebra. Derived events are caused by other events that involve semantic knowledge. For example, a car accident viewed by a passenger. Derived events often gather a rich set of data from external sources. Clinical system is a derived event-based system. The emergency events in 9-1-1 Emergency Medical Services (EMS) and its representation are considered in this paper to propose a universal event set for clinical system. Based on this project, all real-time events can be classified into two categories: emergency and non-emergency. An emergency event is very critical, rapid and life-threatening, whereas a non-emergency event is normal, important, and significant. These characteristics are applied to name the two broadly classified clinical events as:

- **HOT:** This is an emergency event when the ambulance lights are flashing with the siren flared, implying a critical condition of the patient. A HOT event message consists of minimal data elements that represent patient demographics and the vital sign values. The HOT message is time critical and must be transmitted quickly with high priority.
- **COLD:** This is a non-emergency event. A COLD event is triggered when the condition of the patient is under control. The COLD event message consists of a detailed set of data elements. The message is transmitted in sequence and no prioritization is applied during transmission. The estimated transmission time for this message delivery is 1–3 seconds. The time depends on the resource availability.

The events are represented in message type as follows:

$$E = \{C, T, P\}$$

Here, C represents event code. The HOT event is represented with code C = 0 and the COLD event is represented with code C = 1. This code is used to prioritize the messages. The timestamp T value is obtained from the event triggering time of the clinical system. The set of parameters P of both HOT and COLD events are represented in the HL7-CDA specification. The clinical messaging mechanism designed applied is common for both the events.

iii) Data Classification

Data classification is a process of protecting the contents of clinical messages. The classification of clinical data should follow the classification rules used in EHR [1]. The purpose of data classification is to represent the clinical message with appropriate parameters. For this purpose, the clinical data captured by clinical applications are classified as follows:

-All types of data classified with uniform integrity and confidentiality constraints.

-The data is classified into four categories: personal information, health-related information, non-personal information and non-health related information.

-The parameters will be represented using a generic data type with reference to external sources wherever required.

-All messages will contain personal information parameters that uniquely identify a patient and health-related information parameters.

-A message contains at least one health-related information parameter that can be a narrative or a detailed element.

-Both the EHR system and POS systems will have same set of parameters under each category.

-All the data used for administrative purposes are classified as an individual group.

The classification of data based on events is entirely dependent on the operating application. The classification rules are implemented in this paper for the EMS data set derived from NEMSIS standard. The atomic data elements of the application domain are broadly categorized based on the importance and semantics of the data element. The EMS application is divided into four sections: personal, operational, assessment and treatment.

Each section contains sub-sections, and its data elements are classified into two types: core and desired elements. A core element is an essential data element of the dataset. The desired elements are optional elements collected along with the core elements to form a more extensive and detailed data set. The recommended EMS data set is presented here.

- **Personal:** This section contains personal information about the patient involved in the 9-1-1 call. The patient detail section captures all demographical information required for communication and further processing.
- **Operational**: This section contains non-health related information required for administrative purpose only. The following subsections: vehicle details and incident details fall into this category.
- **Assessment**: This section captures health-related information during assessment of the patient. There are four main sub-sections: patient history, general assessment, complaint-based assessment history and mechanism of injury if any. Each sub-section contains child sections: general, allergies, medications, last meal, events prior and past history. The patient history section consists of neuro-response and assessment findings under general assessment; respiratory, seizure, toxic exposure, cardiac arrest, chest pain, neonatal, obstetric, and trauma under complaint-based assessment and history.
- **Treatment:** This section contains the vital health-related information obtained during treatment provided to a patient. The three important sub-sections under this category are: interventions, medications, and vital signs.

The data classification process identifies the key and essential elements related to a clinical system. The HOT event is mapped to the personal section and treatment section that contains key values required for emergency healthcare delivery. The COLD event is mapped to all sections defined within the clinical systems. When the mapping between an event and its related parameters are complete, a clinical message is generated for transmission.

iv) *Message Template*

Reliability refers to the deliverance of the medical record to the EHR without error in exact-sequence (e.g., prescriptions, examination results, etc.); and the accurate interpretation of the clinical data (e.g., correctness of the clinical terms, body temperature in degrees, and so forth). The HL7-CDA specification uses SNOMED CT [25] as the coding scheme for data validation. Different technologies such as UML, ebXML, and ASCII formats are used for HL7-CDA representation.

Using XML technology, a structured representation of the message is in the form of a template shown in figure 1 is proposed. The message template is a refined version of HL7-CDA specification. Based on the resource constraints and requirements for mobile middleware, the specification is simplified into a message with only one section within the <StructuredBody> element. The simplification rules applied to obtain the message structure are presented.

```
<Clinical Document> := <Header> + <Structured Body>
<Header> := <Parameters>
<Parameters> := <Elements> + <Attributes>
<Elements> := data name
<Attributes> : = values
<Structured Body> := <Section>
<Section> := <Text> + <Observation>
<Text> := narrative value
<Observation> := <Parameters>
```

Fig. 1 Mobile HL7-CDA Message Structure

Rule 1: A template can represent only one clinical report of a patient.

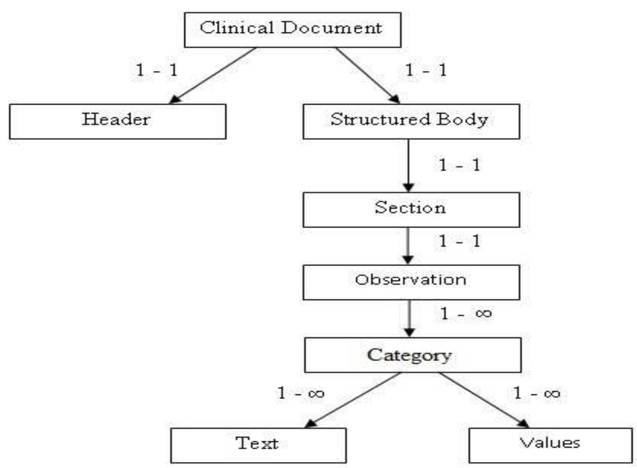

Fig. 2 Elements in a Clinical Document

In a clinical message shown in figure 2, all the event parameters are wrapped by the <Clinical Document> tag. The <Clinical Document> consists of <Header> and <Structured Body> sections. There exists a one-to-one relationship between the <Structured Body> and its content <Section>. All the narrative text values are enclosed within the <Text> element and the detailed clinical data values (both text and numeric) are enclosed within the <Observation> element. The <Observation> element contains <name> tag for each parameter and a <Value> tag for the clinical data values. There exist a one-to-many relationship between <Section>, <Text>

and <Observation> sections. This implies that there can be different narrations and observations within a section. However, the applications can limit the number of <Text> and <Observation> sections to only one within a message. This generates a compact message for quick delivery.

Rule 2: Empty nodes are considered as orphan nodes.

This hierarchical representation assures accuracy of clinical data, by strongly connecting the elements with data values. The nodes with 0 or blank or NULL value are not connected to its parent and can be never accessed. The messaging process will eliminate the disconnected nodes and arrange the elements into a sequence of bytes in the order of XML representation. This enables the mobile middleware to generate event messages using the same byte ordering scheme and build an equivalent message template for transmission. Using message template, the eliminated nodes are validated by the receiver and replaces it with NULL value.

The HL7-CDA specification defines the data elements in traditional ASCII encoding scheme. In mobile computing, UTF-16 (16-bit Unicode transformation format) and UCS-2 (2 byte universal character set) encoding schemes are widely used. Mobile operating systems like brew, windows mobile and symbian OS uses UTF-16 as the native internal text representation and UCS-2 is used in language environments like Java and Python [21]-[22]. Both of these implementations return the number of 16-bit words rather than Unicode characters. A ‘character’ is an undefined unit in Unicode. Hence, inconsistency within the system arises due to the ASCII representation, where Unicode ‘characters’ are returned instead of fixed-size ‘bytes’. The message returns 16-bit word message code to mobile agent for consistency.

B. Mobile Agent Structure

A mobile agent serves as a message carrier representing its master: the mobile client. The mobile agent consists of a header, a main and a run sections as shown in figure 3. This hierarchical structure acts as the message wrapper for the HL7-CDA message template. The mobile agent consists of three components: B_c (code), B_d (data), and B_s (state). The agent code, B_c is presented within the main section of the mobile agent structure that contains the logic of the agent. The B_c must be independent (in form of a byte stream or a local file), readable and executable by the distributed mobile middleware within the network, so that it can be moved easily. The data, B_d is the message template with clinical data. The state, B_s provides the required attributes for agent execution after migration. During the execution, the agent accesses the state of the location and makes changes, if required. These changes are made permanent after the complete successful execution of the agent code.

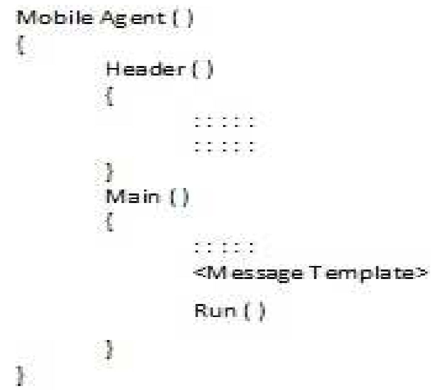

Fig. 3 Mobile Agent Structure

The header section consists of a set of attributes for consistent message delivery. The header attributes contain a set of attributes to specify: sender, receiver, location and action. The attribute RoleID contains an agent global name. There should be only one agent running within the distributed EHR system with a name. The process of assigning global names is out-of-scope of this paper. The MsgCode is a 16-bit alphanumeric value, internally assigned for message template to achieve consistent message delivery. The ActionCode attribute specifies the event code (HOT or COLD). The sender and receiver information is indicated in the OriginInfo and DestInfo attributes. These attribute values are used to establish the exactly-once delivery.

The attribute Location specify the location from which the message is transmitted including the GPS coordinates of the location. The location values are represented as *(x1, y1, x2, y2)* coordinates. The longitude value is represented in the *(x1, y1*) system and latitude value is represented in (*x2, y2)* system. The message template container, MsgContent, is defined as a simple attribute that can hold the XML representation of a clinical message template. The object state contains all the agent attributes, which is marshaled for transmission.

The main section defines methods for remote execution. In our project, a mobile middleware called AMMA which is a Agent based Mobile Middleware Architecture is developed to handle mobile clinical communication. In AMMA, the clinical message template is stored in the private data space as a string literal. The methods to load the string literal and to serialize the data object are specified. This data object is loaded dynamically during the agent migration. Also, the memory space is pre-allocated for mobile agent.

The HL7-CDA compatible message template is represented as a string literal in the private data space of the agent, and is processed using a string intern pool method. In this method, a single-index data structure is used to store the active message object for reference. Only one instance of the message exists in the table at a time. When a message is created, the string intern pool is checked for duplication. This optimization technique provides ‘completeness’, since strings are immutable and can be shared without fear of data corruption. Despite the fact that the local memory will eventually be released, the memory used by the string object will be allocated until the application is terminated.

The run section consists of a content access procedure for message delivery and acknowledgment delivery. A private method, referred as the Move ( ) method, will be executed after the migration. The run section contains methods for internal processing and external processing (mobile agent operations). The code required for clinical message delivery is added as Move ( ) method.

The above specified mobile agent structure is hierarchical and non-blocking. All sections are executed exactly-once and the eventual consistent execution assures that the message content are accurate.

i) Acknowledgment Receipt

Mobile HL7-CDA messages are ASCII messages and the standard requires that they be "human readable". Every time an EHR system accepts a message and consumes the data, it is expected to send an acknowledgement message back to the mobile client. The mobile agent is expected to keep on waiting until it has received an ACK message. The golden rule to be adopted in EHR environment is: only send back an ACK message when you have consumed the data in the message. The key concept in the ACK protocol is the Message Control ID. This is a unique number which every clinical message has in its header. A valid ACK will echo this ID back in the agent header. The mobile agent generates the acknowledgment message based on the receipt of the EHR by the system. When an ack message is received, the mobile middleware AMMA retrieves the message status and discards the mobile agent. The flexibility of the messaging standard allows application developers to create applications that are not required to handle clinical events in its entirety.

C. Message Generation

A general schema for clinical data representation including the specification of the resources and associated procedures required to map clinical data has been explored by the canon group, an informal organization of medical informatics researchers. They recommend a message template specifying the metadata and a set of attributes for documenting a real-time clinical event. The information encoded in the application profile is applied for message generation, thus allowing dynamic messages related to real-time events. A discrete mechanism that unambiguously generates message template is shown in figure 4.

The discrete mechanism is defined as follows: the R-MIM represent the classified datasets based on the real-time events. The abstract schema generated from R-MIM is used for validating the raw data obtained from the application. The validated data is merged with the HL7-CDA message template to generate the mobile message for clinical communication. The message generation procedure applies a bulk loading technique based on the metadata of the mobile clinical application.

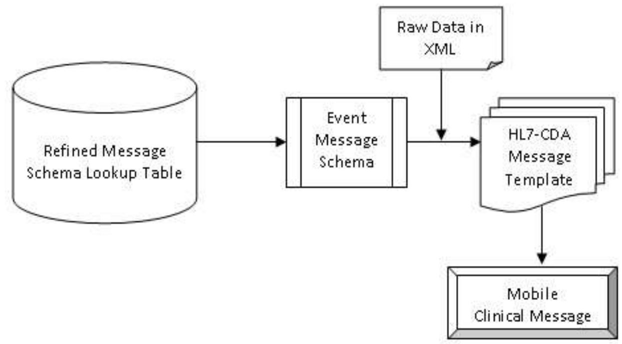

Fig. 4 HL7-CDA Message Template Generation Procedure

Metadata is the structured information about the messaging process that acts as the key to ensure the availability, accessibility and reliability of the information source. The metadata clearly defines the information related to the clinical data contained in the message template. The metadata is represented in the message template by the mandatory and optional header attributes. Most of these attributes are purely document-related (for example, the sender information and receiver information of the patient's medical record). In AMMA, the messaging requirements of the application and environment variables are specified using an application profile. The application profile is used along with the metadata to represent the header attributes of the message template. Some of the application profile elements may apply to the application environment; others may be viewed as request for services to be provided by the EHR system.

Bulk-loading Technique

Message templates are generated according to the event triggers. When an event occurs, an instance of the message template is generated. The HL7-CDA message template represents different categories of data elements within the <section> element. The clinical data is loaded within <section> from the application dataset. In AMMA, a unique content refining technique called bulk-loading is applied to generate the clinical message. In bulk-loading technique, the data elements are assorted and grouped as a single section by the middleware interface. The grouped elements are loaded as a bulk of data elements within the <section> element using XML API. This technique proves to be an efficient and faster approach to generate message templates.

V. Test and Evaluation

The proposed mobile HL7-CDA message structure is compared with the widely used text-based message specifications of SOAP, HTTP and SIP for its ability to represent data in a hierarchical structure. The characteristics of message specifications considered for this study are shown in table 1.

TABLE I

TYPES OF MOBILE CLINICAL MESSAGE SPECIFICATIONS

Message	SOAP	HTTP	SIP	AMMA
Header Type	XML	MIME	ASCI I	ASCII
Body Structure	Multi-level	Multi-level	Singl e	Single
Simplicity	Yes	Yes	Yes	Yes
Confidentiality	Yes	No	No	Yes
Correctness	No	No	No	Yes
Accuracy	No	No	No	Yes
Versatility	Yes	Yes	Yes	Yes

All message specifications adopt a header and a body structure. The message structure is analyzed based on its simplicity in structure, attributes for confidentiality, validation techniques for correctness of data, check mechanism to assure accuracy and its ability to accommodate different data types related to a variety of events. Assuming CDA templates with varying set of data are generated simultaneously from the mobile application, the mobile message structure of AMMA, SOAP, HTTP and SIP are captured for analysis. In introducing mobile agent as wrapper, a new dimension of analysis is required. For this study, templates are generated using 10 different events using the e-PCR tool. The resulting messages are compared using the template size and the message size. The outcome of this study is shown in table 2.

TABLE II
MESSAGE SIZES IN CLINICAL MESSAGE SPECIFICATIONS

Template Size	AMMA	SOAP	HTTP	SIP
0	3.4	3.75	3.52	3.66
2	5.6	6.4	6.75	6.64
5	8.5	9.1	9.1	8.74
9	12.68	13.2	12.55	12.7
11	14.6	15.0	14.65	14.75
14	17.4	17.99	17.82	17.74
16	19.5	20.1	20.2	19.9
19	21.6	22.99	23.4	22.89
21	24.5	25.0	24.7	24.78
27	30.7	31.4	30.55	30.7

Because the messages are wrapped using a number of attributes in the header and body section of each message specification, there is a considerable variance in the size of the message. Shown in figure 5 is the corresponding variance in mobile message generated using HL7-CDA message template. This shows that the AMMA message is compact than the related messages. After conducting100 trials, it was observed that the wrapper size is about 0.2 – 0.3% of the message size and with varying template size. The wrapper size remains consistent to be utilized by secured communication protocols such as TCP/IP.

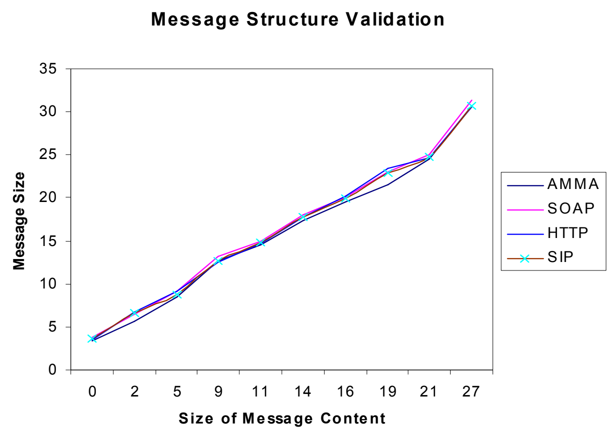

Fig. 5 Message Size of AMMA, SOAP, HTTP, and IP Specifications

VI. CONCLUSION

The results show that AMMA generates light-weight message than other message formats. The message is subject to minimal or no overhead and consumes fewer resources in terms of memory. This enables the agent migration for message delivery to be safe and faster. When the message template is compliant at both communicating ends, then the message is said to be consistent. The compatibility check is performed by using the header attributes of the mobile agent. The good performance of the mobile message generation methodology is in part due to the fact that mobile agent structure is programmatic and less verbose. In case of CDA templates with no external references and links, mobile agent structure is simple. So, these templates are best suitable for reliable delivery of the records to an EHR data server.

REFERENCES

1) Canada Health Infoway, "Electronic Health Record Info structure (EHRi) Privacy and Security Conceptual Architecture". [Online]. http://www2.infoway-inforoute.ca/Documents/EHRi-Exec-Overview.pdf
2) Privacy Commissioner of Canada, "Privacy Act", 1985, [Online]. http://laws.justice.gc.ca/en/P-21/index.html
3) Health Insurance Portability and Accountability Act, "PUBLIC LAW 104–191, 1996" [Online]. http://www.gpo.gov/fdsys/pkg/PLAW-104publ191/pdf/PLAW-104publ191.pdf
4) Lawrence Harte, Introduction to CDMA - Network, Services, Technologies, and Operation, eBook, 2004.
5) Groupe Speciale Mobile: GSM World, "History of GSM", [Online]. http://www.gsmworld.com/about-us/history.htm
6) C. Lindemann and A. Thümmler, *Performance analysis of the general packet radio service*, Computer Networks: The International Journal of Computer and Telecommunications Networking, 2003, vol. 41:1, pp.1-17.
7) IEEE 802.11 Wireless Local Area Networks: Working Group, "Policies and Procedures", [Online]. http://www.ieee802.org/11/Rules/rules.shtml
8) Lars Marius Garshol, "BNF and EBNF: What are they and how do they work?" [Online]. http://www.garshol.priv.no/download/text/bnf.html
9) Canadian Institute of Health Information, "Data Dictionary Aligns with CIHI Strategic Directions", [Online], http://secure.cihi.ca/cihiweb/en/downloads/Datadictionary_aligns_with_CIHI_strategic_directions_e.pdf
10) Clinical Data Interchange Standards Consortium, "CDISC Technical Roadmap", [Online],http://web.archive.org/web/20071027092935/www.cdisc.org/standards/index.html
11) Health Level 7 Organization, "V3 Messaging Standard". [Online]. www.hl7.org.

12) L. Schilders and D. Segers, Medical EDI message specification and interchange formats, Study on Health Technology Informatics, 1993, vol. 6, pp.149-155.
13) John Berge, *The EDIFACT Standards*, Book, Blackwell Publishers, 1994.
14) J. Starren and S.B. Johnson, *An Object-oriented Taxonomy of Medical Data Presentations*, Journal of American Medical Information Association, 2000, vol. 7:1, pp. 1–20.
15) R.H. Dolin et al., *HL7 Clinical Document Architecture, Release 2.0*, Journal of American Medical Informatics Association, 2006, vol. 13:1, pp. 30 -39.
16) Request for comments: 2616, "Hypertext Transfer Protocol – HTTP/1.1", [Online]. http://www.ietf.org/rfc/rfc2616.txt
17) W3C, "SOAP Version 1.2 Part 1: Messaging Framework (Second Edition)", [Online]. http://www.w3.org/TR/soap12-part1/
18) S. Berger, H. Schulzrinne, S. Sidiroglou, and X. Wu, *Ubiquitous computing using SIP*, In Proceedings of the 13th international workshop on network and operating systems support for digital audio and video, 2003, pp. 82-89.
19) P. Zhao , S. Nusser and L. Miller, Design of field wrappers for mobile field data collection, Proceedings of the Tenth ACM International Symposium on Advances in Geographic Information Systems (ACM-GIS 2002), 2002.
20) A. Sahuguet and F. Azavant, Building intelligent web applications using lightweight wrappers, Journal of Data Knowledge Engineering, 2001, vol.36:3, pp.283-316.
21) International Health Terminology Standards Development Organization, "Guidance on the Preparation of Terminology/Classification Mapping Personnel", July 2009. http://www.ihtsdo.org/snomed-ct/
22) International Organization for Standardization, ISO/IEC 10646-1:2000 (E) Information technology–Universal Multiple-Octet Coded Character Set (UCS): Part 1. Architecture and Basic Multilingual Plane, 2000.

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