Medical Data Transmission Using Cell Phone Networks

J Voos, C Centeno, G Riva, C Zerbini, E Gonzalez

Grupo Ingeniería Clínica – Universidad Tecnológica Nacional, Facultad Regional Córdoba, Maestro López esquina Cruz Roja, Ciudad Universitaria, X5016ZAA Córdoba, Argentina.

jvoos@sdct.frc.utn.edu.ar

Abstract. A big challenge in telemedicine systems is related to have the technical requirements needed for a successful implementation in remote locations where the available hardware and communication infrastructure is not adequate for a good medical data transmission. Despite of the wide standards availability, methodologies, applications and systems integration facilities in telemedicine, in many cases the implementation requirements are not achievable to allow the system execution in remote areas of our country. Therefore, this paper presents an alternative for the messages transmission related to medical studies using the cellular network and the standard HL7 V3 [1] for data modeling. The messages are transmitted to a web server and stored in a centralized database which allows data sharing with other specialists.

1. Introduction

Due the availability of new data transmission technologies and new standards for medical studies development, e-health systems have had a sustained adoption in recent years. However, one of the issues for a standard adoption during the medical data transmission is given by the increase in the message size needed to represent the acquired medical data following the data models defined by the selected standard.

In the case of HL7 V3, the requirement to support the reference information model (RIM) for the entities participating in one medical study and the XML [2] tags used for data representation implies the need of high bandwidth for the available communication channel to allow HL7 V3 well formed messages transmission. For this reason, many e-health systems use proprietary representations during transmission and offer HL7 interfaces to represent medical studies already stored at the server side; it means when the transmission from the remote site is completed.

Because of this, the integration between different e-health systems using standards occurs mainly via broadband networks provided by ISPs, where there are no limitations related to the message size during the transmission.

2. Methodology

In order to transmit medical studies represented by the HL7 V3 standard using the cellular network, we developed a customizable telemedicine system to generate, transmit, validate and store partial or complete medical studies according to a particular diagnosis.

The cellular network as a transmission channel was selected based on its availability in remote locations in our country. While cell phone providers are incorporating new technologies (GPRS, EDGE, HSDPA, etc.) allowing different data transfer rates, the system could be configured to improve the available bandwidth for the area where the medical study is performed.

2.1. Architecture

The system is implemented using a service-oriented architecture (SOA). This architecture evolution provides from previous telemedicine projects executed by our team [3] which implies adding new functionalities during each project enhancement. It means adding new services provided by software components written in Java, to manage topics like message transmission, security, HL7 messages processing, front end and database management for the medical studies stored in the web site (Figure 1).

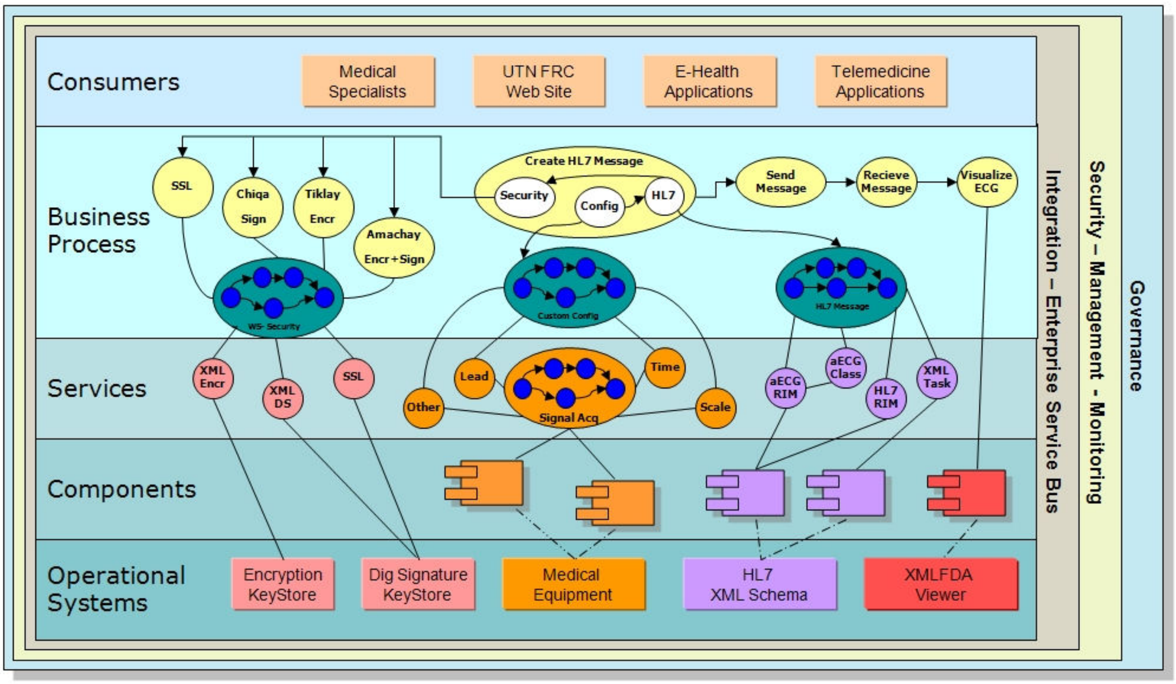

Figure 1. Service Oriented Architecture (SOA) diagram.

The main objective behind this system design is to offer different execution alternatives, providing the necessary adaptability to deal with the problem of having diverse execution environments for telemedicine applications, considering that each region has different needs and available technologies.

This objective is simple achieved through a specific system configuration according to the technical resources available where the medical study is performed and transmitted. During transmission request creation, the system specifies the parameters needed to validate and process messages with the web site module (Figure 2).

```
- <soapenv:Envelope xmlns:soapenv="http://schemas.xmlsoap.org/soap/envelope/"
    xmlns:teleMed="http://teleMed.utnfrc.gic.com">
    <soapenv:Header />
  - <soapenv:Body>
    - <teleMed:customConfig>
        <teleMed:leads>I,V1,V2,AVR,AVL,AVF</teleMed:leads>
        <teleMed:scale>25</teleMed:scale>
        <teleMed:seconds>10</teleMed:seconds>
        <teleMed:security>Amachay</teleMed:security>
      </teleMed:customConfig>
    </soapenv:Body>
  </soapenv:Envelope>
```


Figure 2. Transmission request using SOAP protocol.

Regardless of the selected configuration, all messages are transmitted following the HL7 V3 standard (Figure 3). This architectural decision let us reuse the existing software components associated with XML files processing and HL7 V3 schema validation in order to add new medical studies representations.


```
- <sequenceSet>
  - <component>
    - <sequence>
        <code code="TIME_ABSOLUTE" codeSystem="2.16.840.1.113883.5.4" codeSystemName="ActCode" displayName="Absolute
          Time" />
      - <value xsi:type="GLIST_TS">
          <head value="20030730091733.000" />
          <increment value="0.0010000" unit="s" />
        </value>
      </sequence>
    </component>
  - <component>
    - <sequence>
        <code code="MDC_ECG_LEAD_I" codeSystem="2.16.840.1.113883.6.24" codeSystemName="MDC" />
      - <value xsi:type="SLIST_PQ">
          <origin value="0.000" unit="uV" />
          <scale value="2.500" unit="uV" />
          <digits>36 35 35 35 36 35 33 33 32 31 30 30 30 30 31 31 31 31 31 32 32 31 31 31 31 31 31 31 31 32 32 32 32 31 31 31
            31 33 35 35 35 35 36 36 36 35 35 33 31 32 32 33 35 35 35 35 35 35 35 34 33 33 33 34 35 33 32 32 32 32 32 31 31 31
            31 31 31 31 31 31 31 31 31 31 31 31 31 32 32 32 32 31 31 30 30 31 30 30 31 30 29 29 29 30 31 34 34 34 33 34 33 32
            31 31 31 29 31 30 31 30 29 28 30 30 30 30 28 29 32 32 32 29 30 28 28 27 27 27 27 28 28 28 29 31 30 31 29 29 29 29
            29 30 30 30 31 31 30 30 30 31 33 32 33 31 32 30 29 30 30 30 30 30 30 30 30 30 31 30 30 30 30 28 27 26 26 28 29 30
            30 31 32 33 32 33 32 33 34 34 33 35 35 35 35 33 34 32 30 30 30 28 29 30 29 29 29 29 29 29 30 29 30 29 29 30 29 29
            29 30 30 29 30 29 29 29 29 28 28 29 29 30 32 31 31 31 30 31 30 31 31 32 33 33 32 31 30 30 29 30 30 30 30 30 30 30
            30 30 30 31 32 31 30 30 30 30 29 29 29 28 28 27 27 29 32 31 33 34 34 35 34 34 34 34 34 35 35 35 34 34 37 35 35 35
            35 35 35 33 34 34 33 34 33 33 35 33 36 35 34 32 30 29 29 27 26 27 26 27 28 30 31 30 30 28 28 29 29 30 30 31 33 33
            33 34 33 33 32 31 29 31 29 30 30 30 30 30 30 32 30 33 34 34 34 35 35 36 34 37 37 37 37 37 35 36 38 36 35 37 37 34
            34 32 33 35 35 36 37 38 38 39 39 39 40 43 43 44 46 46 45 46 48 48 47 49 51 51 51 52 52 53 54 54 54 55 55 55 55 57
            58 57 58 58 58 58 57 56 55 54 54 54 53 51 47 47 45 43 40 40 39 39 37 37 36 36 36 35 36 33 33 35 35 37 35 37 35 34
```


Figure 3. ECG signal representation using the FDA XML standard.

The system is based on a producer and a consumer module, while the communication between these modules is implemented by web services using SOAP protocol for message transmission. The producer module includes libraries that require a Java Runtime Environment version 1.4, 1.5 or 1.6, using Windows or Linux operating system. The consumer module runs on a web site hosted at the university using a Java application server version 1.5.

2.2. Security

Most telemedicine applications provide security at transport level, basically to keep the message size reduced and avoid encryption algorithms and digital signature complexity at both communication channel ends. The main issue associated with this security level is that the message could be modified at one intermediate point without detection, ensuring security only in the communication channel implementing a HTTPS session between the requester and the provider.

In our system the communication is protected by message-level security implementation using WS-Security and W3C XML Encryption [4] and XML Digital Signature [5] recommendations to encrypt and sign messages respectively. This approach ensures message integrity end to end because the messages are encrypted and/or digitally signed before transmission. Only the recipient has the valid credentials to decrypt the messages using a key store that contains the certificates exported by the message provider for message decryption. It facilitates detection of message changes during the transmission.

The message level security ensures confidentiality, integrity and authentication for patient data and medical parameters with a more effective method than transport level security using SSL.

3. Results

For the field tests, two medical studies represented by the HL7 V3 standard were used: laboratory report and electrocardiogram. For laboratory reports alternatives were checked with 4, 12 and 20 components; while electrocardiogram signals used during the tests have the following leads combinations: 3, 6 and 12 with 20 seconds as duration and 25 mm/sec as scale.

In all the variants mentioned above, the transmitted messages contain all the mandatory fields required by HL7 V3 standard to represent the reference models (RIM) associated with entities like patient, specialist, place/date for the medical study and data acquisition device.

These medical studies were saved in one laptop to be transmitted through GPRS network using two different GSM modems. One of them uses 2G technology (Motorola G24 with RS-232 connectivity), while the other one supports 3G technology (Huawei E166 with USB connectivity). Each of them uses cellular phone networks from different providers. Relating security, four options were implemented: no security, digital signature, encrypted and signed and encrypted.

Fifteen tests were executed at different times of day for each of the alternatives associated with the medical studies to validate. These tests were conducted in 3 remote areas located in the province of Cordoba with the objective of evaluating the system behavior in response to different cellular network bandwidths. Despite the increment of the transmission time associated with the GPRS network conditions, all of the messages were transmitted successfully. Each value for the figures 4 and 5 represents the average times in seconds using 2G and 3G technologies for each of the transmitted alternatives associated with medical studies.

	3 leads		6 leads		12 leads	
	2G	3G	2G	3G	2G	3G
Plain Text	8,43	2,27	8,62	5,72	12,78	8,15
Signed	14,67	6,78	17,21	7,89	26,31	10,53
Encrypted	28,33	11,89	38,29	12,47	97,01	18,01
Enc + Sign	29,39	13,47	36,25	13,51	90,22	25,03

Figure 4. Average transmission times in seconds for electrocardiogram alternatives.

	4 components		12 components		20 components	
	2G	3G	2G	3G	2G	3G
Plain Text	6,17	2,02	8,12	4,16	9,34	5,01
Signed	13,46	4,12	17,34	8,92	19,12	8,13
Encrypted	15,12	8,43	22,18	10,21	23,46	13,12
Enc + Sign	20,12	11,16	27,19	9,16	29,18	15,81

Figure 5. Average transmission times in seconds for laboratory report alternatives.

Figure 6 shows a graphical comparison between the average times for each security combination using 2G technology.

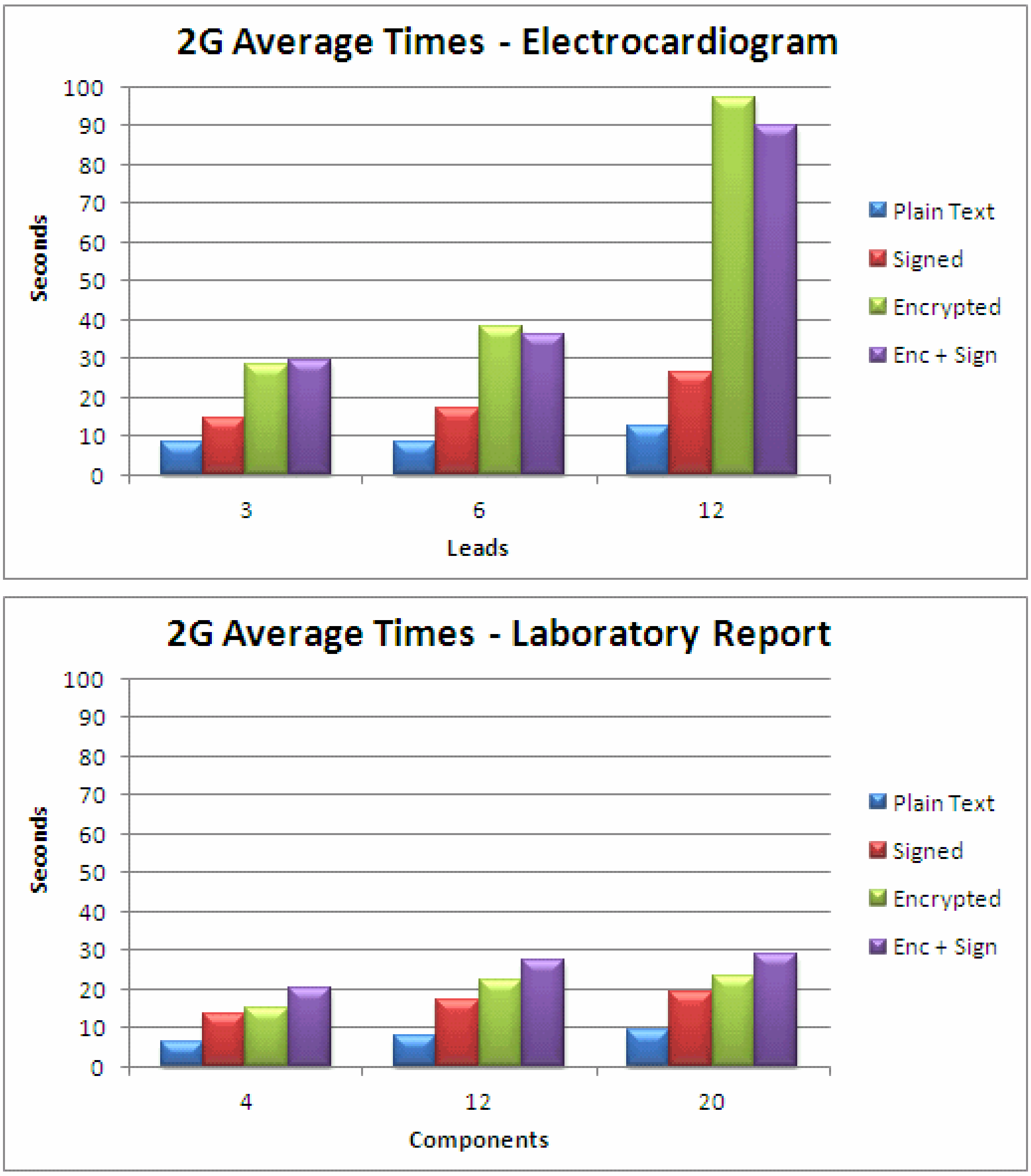

Figure 6. Average times using 2G technology.

Figure 7 shows comparative data related to 3G technology average times.

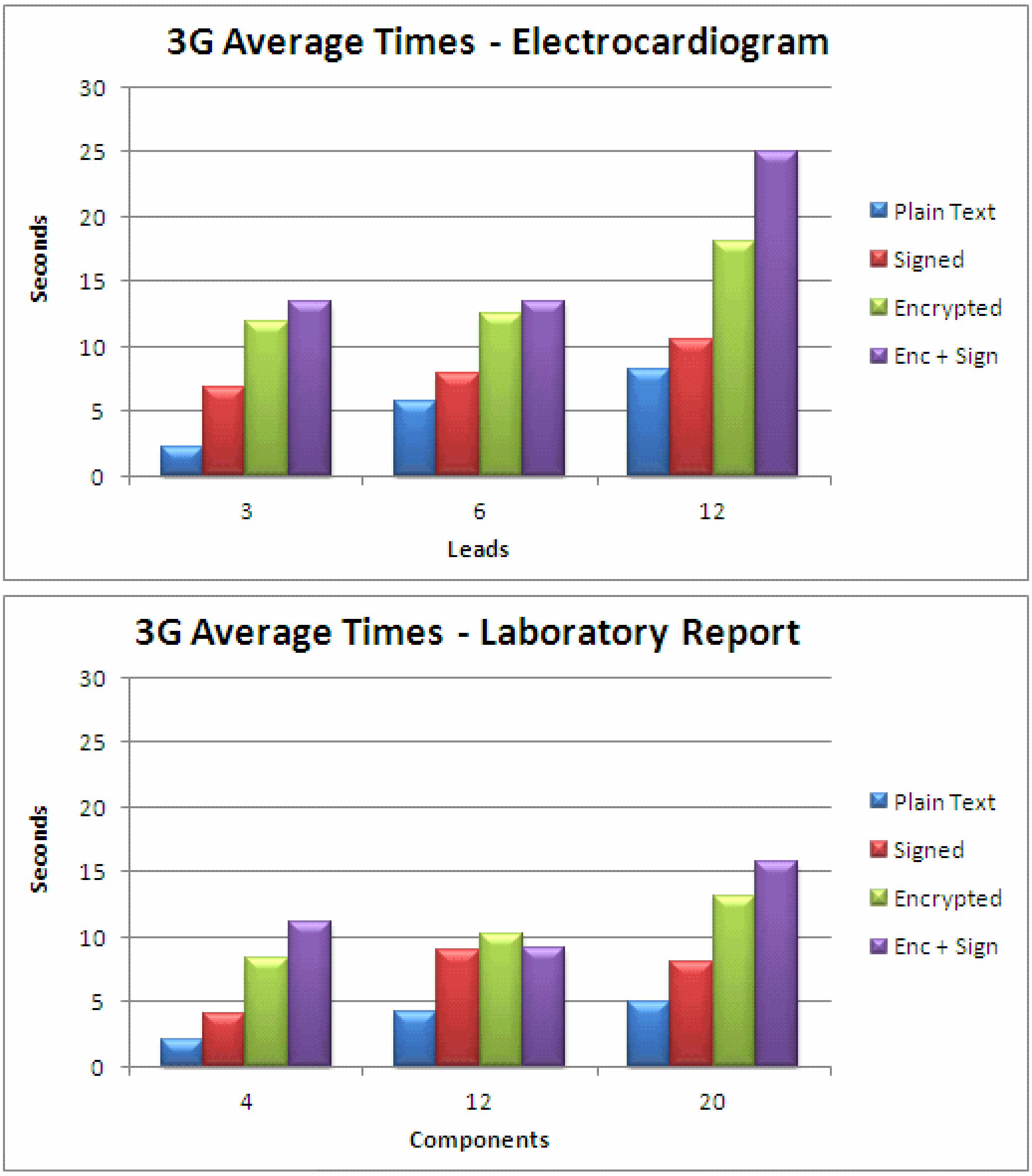

Figure 7. Average times using 3G technology

4. Conclusion

This initiative validates the technical feasibility of enabling the HL7 V3 standard for laboratory reports and electrocardiograms transmission using the cell phone network, through field tests in remote areas where the available medical infrastructure demands using of telemedicine. In this way any telemedicine system with a HL7 V3 interface can receive these studies without transformation and/or integration efforts for their processing.

With the purpose of managing available bandwidth issues which affect the medical study transmission; a software services group was developed in order to build HL7 V3 messages containing only critical data needed to formulate a study first diagnosis, together with the possibility to choose different levels of security during the transmission. Through the implementation of new software services; the system architecture allows new interfaces in response to different diagnoses and adoption of additional HL7 standards for other medical studies.

References

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[3] Voos J, Vigliecca N and Gonzalez E 2007 Web based aphasia test using service oriented architecture (SOA) *J. Phys.: Conf. Ser.(2007) 90 012003*

[4] XML Encryption Syntax and Processing, W3C Recommendation, 2008. http://www.w3.org/TR/xmlenc-core/

[5] XML Digital Signature Syntax and Processing, W3C Recommendation, 2008.