A new SCP-ECG module for telemedicine services

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Abstract: - This paper presents the design and development of an application on Electrocardiogram (ECG) management area. This application makes possible the receiving, processing, storing, and retrieving ECG data. The ECG data are recorded with digital ECG devices (carts) constructed by various manufacturers and are transmitted to the telemedicine services workstations (hosts). In order to overcome the incompatibilities between the cart manufacturers (e.g. data format) the application adopts the utilization of Standard Communication Protocol for Computer assisted Electrocardiography (SCP-ECG protocol). The application development is also based on a platform that complies with ITU-T standards, in order to guarantee the interaction and interoperability of an H320 (ISDN) or H323 (IP) user (cardiologist or cardiology fellow). At the time of writing this paper, the application (reception and manipulation of SCP-ECG complied data) has been tested with carts, and with SCP-ECG compatible data files. The proposed module is going to be used as stand alone application or as a plug-in to be incorporated in telemedicine platforms such as the OTE-TS telemedicine service, a telematics service for telemedicine applications, developed for the Hellenic Telecommunication Organization (OTE).

Key-Words: - SCP-ECG, Telemedicine, Vital Signs, Electrocardiogram, Electrocardiography

1 Introduction

Novel telemedicine services implementations establish electronic workspaces suitable for the organization of the physicians and medical service providers (SP) activities during the execution of diverse applications for e.g. tele-training, tele-diagnosis, tele- or common consultation, etc.

These services handle patient demographics data, medical examination data results, medical image capturing, digitizing, processing, printing, and storing in a local database [1]. Incident composition is also a supported function, which allows the user of the service (MD or MD fellow) to create a collection of medical examination results, medical images, non-personal patient data, possible diagnosis, etc, for transmission, reception, processing or archiving. Telemedicine services may support both on-line and off-line handling of data (e.g. OTE-TS [1]). The former is considered to be an asynchronous session that allows each user to diagnose individually a case. The latter is considered to be a synchronous session that allows the participating users to collaborate in real time in order to make a common diagnosis. A central database is established in order to permit and control the medical data exchange between MDs as well as the storage of incidents for archiving reasons (statistical data extraction etc). Real-time cooperative work is also supported, providing users with high quality audio/video conferences, data sharing and medical images processing. Cooperative work can be based on platforms that support ISDN and/or IP communication technology.

This paper presents the design and development of an application that supports the direct import and management of ECG data as an extension in the telemedicine service. In the case of the OTE-TS [1][3][4] which manages Vital Signs - especially the data of electrocardiograms - as pictures (captures from ECG hard copies), the proposed module allows the connection of the ECG carts using different physical links, the administration of ECG data as raw data, the ability of interchange the SCP-ECG formatted files with other applications etc.

2 Electrocardiography and Electro-cardiograms

The electrocardiogram (ECG) is a representation of the electrical activity of the heart. It gives information about the condition of the heart muscle. So the ECG is the recording of voltage changes transmitted to the body surface by electrical events in the heart muscle, providing:

- direct evidence of:
  - cardiac rhythm,
  - conduction
- indirect evidence of certain aspects of
  - myocardial anatomy,
  - blood supply and
  - function.

Electrocardiography is the leading method for non-invasive diagnosis and detection of coronary heart disease. It is estimated that more than 1.5 billion ECU, are spend every year in European Community (EC) for routine diagnosis and screening purposes [5]. In view of high costs of ECG tests and the necessity for continuity of health care, it is important to:

- establish a way for easy communication of the results of cardiac tests between various health care providers,
- organize an electronic patient health record.

Nowadays, the electrocardiographs are computerized, stand-alone machines with interconnection capabilities. So, some ECG recorders can be connected to an ECG management server, establishing an ECG network, for storage, viewing, measuring, forwarding data, etc. However, this solution has intrinsic problems, because every manufacturer has its own connection method, data format, user identification, machine authentication, etc. These problems make the ECG data manipulation dedicated to one manufacturer's machines, which in case of the OTE-TS telemedicine platform is out of the telemedicine network design concept. A solution to the various manufacturers' incompatibility problem is the adoption of a globally acceptable protocol that has to standardize the communication, the data format and the query messaging between ECG devices and data management servers.

3 Materials and Methods

This section presents global elements of the SCP-ECG [5] protocol referring to data format and also the application design considerations and implementation. It also makes a reference to Digital Imaging and Communications in Medicine supplement 30 another standard for Waveform Interchange [6][7].

3.1 General description of the SCP-ECG protocol

The aforementioned incompatibility problems can be satisfied with the Standard Communication Protocol for Computer-assisted Electrocardiography, version prEN 1064:2002 prepared by CEN/TC 251 [5]. This standard covers the two-way transmission of remote requests and results between digital electrocardiographs (ECG carts) and heterogeneous computer systems (hosts). It defines the rules for the cart to host or cart to cart exchange of data, like patient data, machine's manufacturer data, ECG waveform data, ECG measurement and interpretation results. So, this standard specifies the content and structure of the information, which is to be interchanged between digital ECG carts and computer ECG management systems, as well as other computer systems, where ECG data can be stored. It enables any two such systems to establish a logical link for communication of ECG related data in a standard and interpretable form [8][9].

The protocol defines four data categories of Data Format based on the information content. These categories are presented in Table 1.

Category	Data Sections	Information Description
I	0,1,7,8	Demographics, global measurements and interpretation
II	0,1,2,3,6,(7),(8)	Demographics and rhythm data
III	0,1,2,3,5,(7),(8)	Demographics and reference beats
IV	0,1,2,3,4,5,6,(7),(8)	Demographics, ECG rhythm data, and reference beats

Table 1 – SCP-ECG protocols Data Format Categories

The data sections (7) and (8) contain information optional for export.

The data structure of data sections listed in Table 1 is described in Table 2.

The protocol, also, defines the steps included in the procedure from ECG data acquisition to the final diagnosis and treatment. According to the protocol four steps can be distinguished:

- Acquisition: The recording of the original cardiograph signal from the patient's body using one or more leads.
- Interpretation: The ECG signal analysis on the cart or on the host usually computer generated.
- Overreading: The process where a cardiologist or a cardiology fellow, reviews the computer-generated interpretation of an ECG. In this step he is able to check the reliability of the

interpretation or to write his opinion into the interpretation text.
- Confirmation: The final process before the clinically acceptable text for diagnosis and treatment. In this step an expert reviews the text generated in interpretation or overreading procedures, in order to make the final corrections.

Section	Type	Information Description
0	Mandatory	Pointers to data areas in the record
1	Mandatory	Header Information – Patient data/ECG acquisition data
2	Optional	Huffman tables used in encoding of ECG data (if used)
3	Optional	ECG lead definition
4	Optional	QRS locations (if reference beats are encoded)
5	Optional	Encoded reference beat data if reference beats are stored
6	Optional	“Residual signal” after reference beat subtraction if reference beats are stored, otherwise encoded rhythm data
7	Optional	Global measurements
8	Optional	Textual diagnosis from the “interpretive” device
9	Optional	Manufacturer specific diagnostic and overreading data from the “interpretive” device
10	Optional	Lead measurements results
11	Optional	Universal statement codes resulting from the interpretation

Table 2 – SCP-ECG protocol Data Structure

The DICOM Waveform Interchange Standard supplement 30 is a standard supporting the interchange of waveforms, such as 12-lead ECG data and time series data, time synchronization frame of reference, annotation capabilities and waveform synchronization the imaging context. Furthermore, it is meant to address waveform acquisitions which will be analyzed with other data which is transferred and managed using the DICOM protocol. It allows the addition of waveform data while if maintains referential relationships to other data collected in a multi-modality environment, including references for multi-modality synchronization.

In the Web there are many free DICOM waveform viewers available to be downloaded, in order to view ECG waveforms. On the opposite side, in the Web there are no waveform viewers able to support the SCP-ECG format. For this reason, this paper has been based on the SCP-ECG protocol.

3.2 Application design - implementation

Adopting the SCP-ECG protocol, the first step to the implementation of this project was the investigation for manufactures supplying carts compatible with the SCP-ECG protocol, and also for files constructed according to the above data format, in order the application software to be designed and developed.

The cart selected during the implementation of this work was supplied with an active-X, which is responsible for the communication between the host and the cart. The data format of the files generated by the active-X, are compliant with SCP-ECG category II, which means that Demographics and ECG Rhythm Data can be exchanged [8]. Also, SCP-ECG compatible files used for testing purposes were available in the OPENECG portal [11].

The files used for the application development and testing up to now, have the following characteristics:

- First set of files
    - Number of leads = 8
    - Patient Data = Yes
    - Encoding = Huffman [5][12][13][14]
    - Second Differences used = YES
    - Reference beat subtraction = No or YES
    - Leads simultaneously recorded
- Second set of files (coming from the cart)
    - Number of leads = 12
    - Patient Data = Yes
    - Encoding = No
    - Second Differences used = NO
    - Reference beat subtraction = NO
    - Leads simultaneously recorded

The physical links between carts and hosts, in order the data transmission to be allowed, include local and remote connections. Thus, in local connections a RS-232-C link can be established between a computerized ECG cart and an ECG management system. On the contrary, remote connections can be established either using TCP/IP protocol connections or through a phone line with a V.22bis modem. Fig. 1 shows the types of connections.

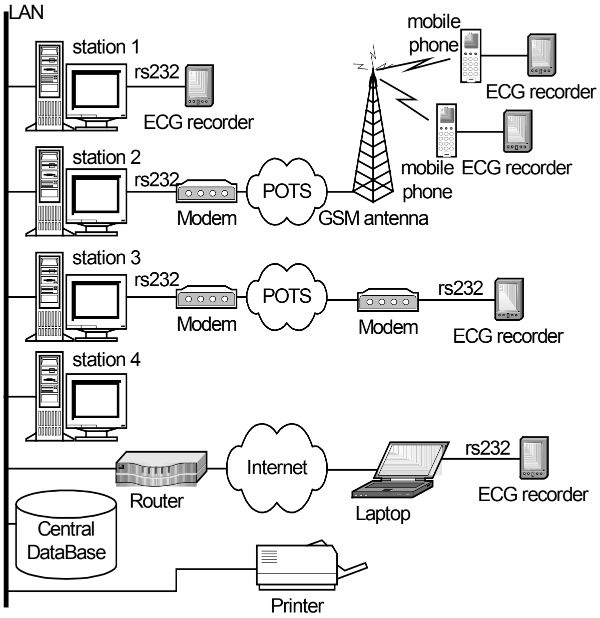

Fig. 1 - Different types of connections can be used for ECG data transmission

The current project was based on both direct links using the RS-232C interface for local connections and the use of modems for remote connections.

After the ECG files have been stored on the host, all included information can be presented to the user.

The interface designed and implemented during this project is presented on Fig.2. This interface is used on receiving – processing stations. It is divided in nine regions. Briefly these regions are:

1. Teleconferencing management
2. Patient, Doctor, institution data
3. ECG waveform animation area
4. Measuring tools
5. Database functions
6. ECG preview area
7. Printing functions
8. ECG interpretation text
9. Other Vital Signs referring to this patient

The role of each region included on the user interface is described below:

Teleconferencing management. User can dial (ISDN or IP networks are supported) another user in order to establish a teleconferencing session. Audio, video and data transmission are available.

Patient, Doctor, Institution Data. Data included on the selected SCP-ECG file are presented in this area. Also, patient, doctor and institute filtering operations for retrieval or statistical purposes are available.

ECG waveform animation area. In this area, the user is able to select a lead from those included in the received ECG and view the waveform designed as when it was recorded. The designed waveform can be zoomed in or zoomed out.

Measuring capabilities. The user can makes manual measurement on the waveform.

Database functions. When a patient record is selected the user can choose from the files referring to him, a specific file to process.

ECG preview area. This area enables user to view all lead recorded about the selected patient. Currently are supported the preview up to 12 leads.

Printing management. It gives the capability of printing the ECG waveforms, patient and other data.

ECG interpretation text. In this field, the interpretation text can be viewed, modified or edited in order to have the final interpretation text for the diagnosis and treatment.

Other vital signs. Here, data for blood pressure, body temperature and oxygen saturation are presented. These fields and diagrams can display the data referring to this patient in a given period.

An important function of the implemented application is the teleconferencing – tele-consultation capabilities. The tele-consultation is defined as the situation in which two users need to discuss the same patient data, while not using the same workstation, being in different parts of the hospital or in different geographies.

During a teleconference session, both sides communicate through real time hi-quality audio and clear video (up to 30 frames per second). Using the data exchange capabilities the co-operators can discuss a patient's case, by means of the following steps:

- The selected SCP-ECG formatted file is transferred to the other side.
- The SCP-ECG formatted file is opened on both sides.
- The ECG waveforms and patient data are displayed on both participants.
- The selected by one user waveform is displayed on the region 3 (Fig. 2), where it is animated, representing the rhythm when it was recorded.
- Using the controls of the region 4 (Fig. 2), each user can draw a line on the ECG waveform displayed on region 3, measuring in this way the desired "distance". This action is displayed simultaneously on both sides. So the measuring lines are used also as a marker displaying in both sides the critical portions of the waveform.

Special timers and controllers are used to establish an appropriate signalling between stations in order to avoid conflicts between users. In this way, the one side makes operations only if the other side allows it. All the operations are transmitted to the other side as graphical events or commands in order to achieve an excellent performance.

The use of teleconference facility is very helpful, especially in cases where, the received waveforms contain artifacts, the interpretation of an ECG waveform is confused, the user is inexperienced, the expert responsible for the receiving station is absent or busy, or when a second opinion is needed.

Fig. 2 - Applications user interface

4 Discussion

The developed extension for the Tele-Medicine service enriches the Hellenic's Telecommunication Organization (OTE) service with ECG data management capabilities. Thus, using this application a user can receive electrocardiogram waveforms from devices compatible with the SCP-ECG protocol constructed by various manufacturers. Processing of electrocardiogram waveforms, modification, storage, query, and retrieval of ECG files are also supported functions. The adopted protocol with its structured data format makes possible the query of patient health records stored in various health care providers, in order to guarantee the continuity of health care.

Taking advantage of the high-end technology and the fast communication networks the establishment of a teleconference environment between users is made possible. Audio, video and data communications is now very reliable and fast, giving clear video, high quality audio, and fast data transmission. An inexperienced user, by means of teleconference facilities featured in the application, could benefit regarding a possible consultation with another (e.g. more experienced) user.

5 Conclusion

Thanks to the SCP-ECG standardization the establishment of a network consisted of servers belonging in various health care providers is possible. Each of them can store electronic patient records. Through the network and using unique patient identification the reassurance of continuity of care is possible. By means of a continuously updated list with health care providers compliant to the SCP-ECG protocol, every time a patient visits a health center, all the historical data referring to him can be retrieved. In this way, each doctor is provided with all necessary data to make a more accurate diagnosis.

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