Structuring the e-SCP-ECG$^+$ protocol for multi vital-sign handling

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***Abstract*—Standard Communication Protocol for Computer-assisted Electrocardiography (SCP-ECG) has been standardized in order different ECG devices to be able to communicate with computers through the same language. This paper proposes specific extensions on SCP-ECG protocol structure and introduces the enhanced SCP-ECG$^+$ (e-SCP-ECG$^+$) protocol. e-SCP-ECG$^+$ is backward compatible to the SCP-ECG protocol while it is able to handle more vital sign and demographic data. It also overrides some limits of the original protocol. The proposed extension has been implemented both as new tags in existing sections and as new sections of the SCP-ECG protocol appended to the original file format.**

I. 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. The modern communication networks make the establishment of a cooperative scheme between two or more computer based machines easy. Also the modern medical monitors offer the facility of data transmission to computers sited far away.

Many protocols have been proposed in order data acquired from devices manufactured by various manufactures to be able to be transmitted to remote stations and managed by them. Some of the above protocols are: DICOM supplement 30, HL7, ISHNE (Holter Standard Output File Format), EDF+, CEN/FEF File Exchange Format for Vital Signs, IEEE 1073 Standard for Medical Device Communications and SCP-ECG (Standard Communication Protocol for Electrocardiograms).

In some medical cases, the simultaneous transmission both of patient's demographic data and his vital signs measurements is critical. Because none of the above protocols is able to satisfy this requirement, the proposal of a new protocol was a necessity. However, the study of the structure of the aforementioned protocols proved that SCP-ECG on the one hand is well structured and on the other hand allows its extension, and therefore it can be used as a base for the creation of a new protocol that meets our requirements.

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The SCP-ECG (Standard Communication Protocol for Computer-assisted Electrocardiography) [1][2] defines the patient's ECG data structure, the basic demographics format and the rules of the data interchange between the digital electrocardiographs (ECG carts), through which they are acquired, and computer systems (hosts), where ECG data can be stored. Moreover, it gives the ability new sections to be added in order more information to be handled. It also, permits extra demographics data to be added.

The work presented in this paper introduces specific expansions to the SCP-ECG that improve its capabilities. The expanded protocol can be implemented as an independent software component, which may be embedded into any medical IT system (e.g. RIS, Telemedicine, etc) that lacks such capabilities (vital sign management).

The proposed enhanced SCP-ECG protocol is referred as e-SCP-ECG+ protocol. The enhancement makes possible the transmission and handling of not only the basic patient's demographics and ECG data, but it also includes additional fields for demographic and allergy data and also other vital signs such as the Oxygen Saturation (SPO2), the non invasive blood pressure (NiBP), the body temperature (Temp), the pulse rate, the Carbon dioxide (CO2), and the plethysmographic (PLE) data. These additions meet doctor requirements, which arose during former telemedicine projects that the authors have been involved [3][4][6]. As a result, the e-SCP-ECG+ leads in the transmission and management of a set of valuable indications on patient's health state. In this way, each doctor is provided with all necessary data in order to make a more accurate diagnosis.

II. SCP-ECG's short description

The Standard Communication Protocol for Computer-assisted Electrocardiography, version prEN 1064:2002 prepared by CEN/TC 251 (SCP-ECG)[1][2] was defined in order ECG devices constructed by different manufactures to be able to communicate with computers through the same language.

This protocol covers both the connection establishment between digital electrocardiographs (ECG carts) and heterogeneous computer systems (hosts) and the rule definition for the cart to host or cart to cart data exchange. The exchanged data consist of patient data, machine's manufacturer data, ECG waveform data, ECG measurements and also interpretation results.

The contents of a SCP-ECG formatted file are structured as a set of sections. Each section holds different type of

information.

This paper is based on the 1064: 2002 version of protocol, because it is more flexible than the last one (version A1+). It assumes that the sections responsible for the handling of ECG data are optional, while the last version of protocol defines these sections as mandatory.

III. Additions to the SCP-ECG Protocol

The SCP-ECG protocol, having already a structure able to transfer a large amount of data, has been enhanced in order to hold both more demographic information and vital signs. The protocol defines that section 1 "tags" numbered from 200 to 254 (out of 255) and sections numbered from 128 to 1023 are available for use by manufactures. The use of these "tags" and sections for handling more data results in the creation of a new protocol, e-SCP-ECG+. The e-SCP-ECG+ is flexible and adaptive, because these enhancements are optional, in order to assure that the minimal amount of data, which is necessary for each medical case, is handled. Also, the new "tags' are characterized as optional due to the necessity to overcome national or ethical limitations.

Therefore, according to the necessity for the manipulation of the extra amount of data, we have assigned and used some new "tags" and sections as follows:

A. The New "Tags"

The new "tags" added to the section 1 structure are the following:

Tag	description
200	Second patient ID
201	Patient Nationality (ISO 3166.1 classification)
202	Patient Address
203	Patient Phone Number
204	Patient Religion
205	Birth Place
206	Patient Insurance
207	Memorial History
208	Blood Type
209	File access
210	Access restrictions

B. The New Sections

The new defined sections are the following:

- 200 for oxygen saturation (SPO2) and pulse rate data,
- 201 for body temperature data,
- 202 for capnography data
- 203 for non invasive blood pressure and pulse rate data
- 204 allergy
- 205 SPO2 plethysmography (PLE) data

Each new section follows the SCP_ECG protocol general sections format. So, each section consists of a Section Identification Header and a Section Data Part.

B.1 The Section Identification Header

The Section Header, as presented in the SCP-ECG protocol specification, holds the following information:

Byte	description
1-2	2 bytes for the 16 bit CRC-CCITT over the remaining section
3-4	2 bytes for the Section ID number
5-8	4 bytes for the Section length over the entire section
9	1 byte for the Section Version Number
10	1 byte for the protocol section version number
11-16	6 bytes Reserved for future use

B.2 Section 200 (SPO2 – Pulse Rate Data)

This section contains measurements for oxygen saturation (SPO2), and the corresponding pulse rate. Because of the possibility of interrupted data acquisition, measurements can be stored as data blocks.

B.2.1 If present, the section will start with a "Section ID Header" as defined in paragraph **B.1**.

B.2.2 The data part header contains global settings for the measurement of SPO2 and pulse rate. It is formatted as:

Byte	description
1-2	Time interval between measurements in ms (10^{-6}s)
3-4	Number of measurement blocks

B.2.3 The data characteristics block supplies information about each data block. It has the following format for each data block:

Byte	description	
1-4	Date of acquisition	
	1-2	binary: year in four-digit format
	3	binary: month in two-digit format
	4	binary: day in two-digit format
5-7	Time of acquisition	
	5	binary: hours in two-digit format
	6	binary: minutes in two-digit format
	7	binary: seconds in two-digit format
8-9	binary: the data block length	

B.2.4 The data block contains the measured data for SPO2 and pulse rate.

Byte	description
1	1st value for SPO2
2-3	1st value for pulse rate
4	2nd value for SPO2
5-6	2nd value for pulse rate
etc	

B.2.5 Fig. 1 shows the data part overview

B.3 Section 201 (Temperature Data)

This section contains body temperature measurements. The continuous temperature measurement is not possible in all cases. So this section handles the samples either as distinct values or as a sequence

B.3.1 If present, the section will start with a "Section ID Header" as defined in paragraph **B.1**.

B.3.2 The section data part begins with a header that has the following format:

Byte	description
1	This value indicates the type of data acquisition: 0 = distinct values 1 = a sequence of values

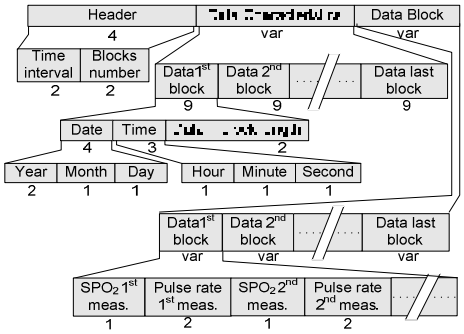

Fig. 1. Overview of the data part holding the SPO2 and pulse rate

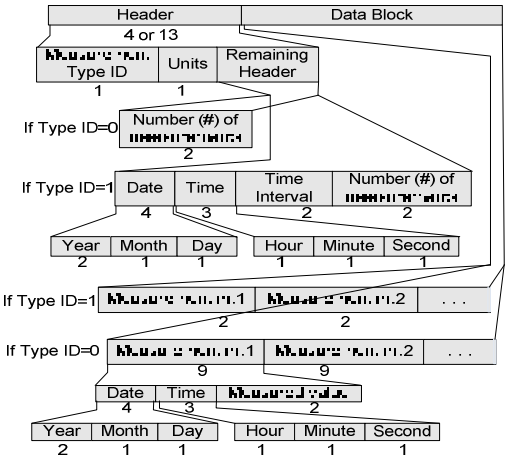

Fig. 2. Overview of the data part holding the temperature data

2 units
0 = Celsius degrees
1 = Fahrenheit degrees

B.3.3 Depending on the type of data acquisition, the header after byte 1 has different format.

B.3.3.1 If the measurements consist of distinct values, the remaining header is the following:

Byte	description
3-4	binary: the number of temperature measurements

B.3.3.2 In the other case, where the measurements acquired as a sequence, the remaining header format is as follows:

Byte	description
3-6	Date of acquisition
	3-4 year in four-digit format
	5 month in two-digit format
	6 day in two-digit format
7-9	Time of acquisition
	7 hours in two-digit format
	8 minutes in two-digit format
	9 seconds in two-digit format
10-11	time interval between measurements ms (10^{-6}s)
12-13	binary: the number of temperature measurements

B.3.4 The detailed information for each measurement is as follows

B.3.4.1 If the byte 1 of the data part header equals 0 (distinct measurements), for each measurement the file contains the next information

Byte	description
1-4	Date of Acquisition
	1-2 binary: year in four-digit format
	3 binary: month in two-digit format
	4 binary: day in two-digit format
5-7	Time of Acquisition
	5 binary: hours in two-digit format
	6 binary: minutes in two-digit format
	7 binary: seconds in two-digit format
	Measured value
8-9	binary: the measured value multiplied x100
10-…	same as bytes 1-9 for the rest of the measurements.

B.3.4.2 In the case that the type of measurements is 1, the data part format is:

Byte	description
	Measured value
1-2	binary: the 1st measured value multiplied x100
3-4	binary: the 2nd measured value multiplied x100
etc.	

B.3.3 Fig. 2 shows the data part overview

B.4 Section 202 (Capnography CO2 Data)

This section contains measurements of carbon dioxide (CO2) in respiratory gas. Those measurements can be performed at specific intervals.

B.4.1 If present, the section will start with a "Section ID Header" as defined in paragraph **B.1**.

B.4.2 The data part header contains data as the date and time of the beginning of acquisition and the time interval between measurements. It is formatted as:

Byte	description
1-4	Date of Acquisition
	1-2 binary: year in four-digit format
	3 binary: month in two-digit format
	4 binary: day in two-digit format
5-7	Time of Acquisition
	5 binary: hours in two-digit format
	6 binary: minutes in two-digit format
	7 binary: seconds in two-digit format
8-9	Time interval between measurements in microseconds (1*10-6s)
10	Units:
	1 mmHg
	2 Torr
	4 %
	5 kPa
11-12	Number of measurements

B.4.3 The data block contains the measured data for systolic and diastolic pressures.

Byte	description
1-2	1st value of carbon dioxide
3-4	2nd value of carbon dioxide
etc	

B.4.4 Fig. 3 shows the data part overview

B.5 Section 203 (Non-Invasive Blood Pressure NiBP)

This section contains measurements for the NiBP. Those

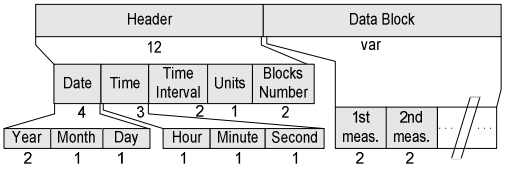

Fig. 3. - Overview of the data part holding the capnograph data

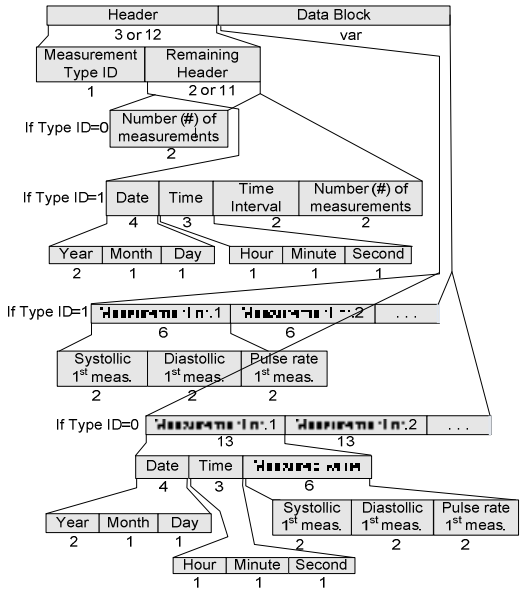

Fig. 4. - Overview of the data part holding the systolic - diastolic blood pressure data

measurements can be performed randomly (as distinct values) or at specific intervals (as a sequence).

B.5.1 If present, the section will start with a "Section ID Header" as defined in paragraph **B.1**.

B.5.2 The section data part begins with a header that has the following format:

Byte	description
1	This value indicates the type of data acquisition: 0 = distinct values 1 = a sequence of values

B.5.3 Depending on the type of data acquisition, the header after byte 1 has different format.

B.5.3.1 If the measurements consist of distinct values, the remaining header is the following:

Byte	description
2-3	binary: the number of NiBP measurements

B.5.3.2 If the measurements are acquired as a sequence, the remaining header format is as follows:

Byte	description
2-5	Date of acquisition
	2-3 year in four-digit format
	4 month in two-digit format
	5 day in two-digit format
6-8	Time of acquisition
	6 hours in two-digit format
	7 minutes in two-digit format
	8 seconds in two-digit format
9-10	time interval between measurements ms (10^{-6}s)
11-12	binary: the number of NiBP measurements

B.5.4 The detailed information for each measurement is as follows

B.5.4.1 If the byte 1 of the data part header equals 0 (distinct measurements), for each measurement the file contains the next information

Byte	description
1-4	Date of Acquisition
	1-2 binary: year in four-digit format
	3 binary: month in two-digit format
	4 binary: day in two-digit format
5-7	Time of Acquisition
	5 binary: hours in two-digit format
	6 binary: minutes in two-digit format
	7 binary: seconds in two-digit format
	Measured value
8-9	binary: the measured value multiplied x100
10-…	same as bytes 1-9 for the rest of the measurements.

B.5.4.2 In the case that the type of measurements is 1, the data part format is:

Byte	description
	Measured value
1-2	binary: the 1st measured value multiplied x100
3-4	binary: the 2nd measured value multiplied x100

etc.

B.5.3 Fig. 4 shows the data part overview

B.6 Section 204 (Allergy Data)

This section contains information about patient's allergy. Its structure follows the structure of SCP-ECG's section 1.

B.6.1 If present, the section shall start with a "Section ID Header" as defined in paragraph **B.1**.

B.6.2 The data part contains information structured as a set of fields. Including a field is optional. Each field is identified by one leading specification byte, referred as "tag", indicating the contents of this block, a two byte unsigned integer, referred as "length", indicating the maximum length of the block value in bytes and zero or more parameter bytes, referred as "value", containing the corresponding data

Byte	description
1	field tag
2	field length
3-…	field value

Field tag 255 marks the end of this section'

B.6.4 Fig. 5 shows the data part overview

B.7 Section 205 (SPO2 Plethysmograph (PLE) Data)

This section contains measurements for SPO2 plethysmograph (PLE) data, and the corresponding pulse rate.

Because of the possibility of interrupted data acquisition, measurements can be stored as data blocks.

B.7.1 If present, the section shall start with a "Section ID Header" as defined in paragraph **B.1**.

B.7.2 The data part header contains global settings for the measurement of PLE. It is formatted as:

Byte	description
1-2	Time interval between ms (10^{-6}s)
3-4	Number of measurement blocks

B.7.3 The data characteristics block, supplies information about each data block, has the following format:

Byte	description
5-8	Date of acquisition
5-6	binary: year in four-digit format
7	binary: month in two-digit format
8	binary: day in two-digit format
9-11	Time of acquisition
9	binary: hours in two-digit format
10	binary: minutes in two-digit format
11	binary: seconds in two-digit format
12-13	binary: the data block length

B.7.4 The data block contains the sequence of the measured data for each block of PLE waveform.

Byte	description
14	1st value for PLE
15	2nd value for PLE
etc	

B.7.5 Fig. 6 shows the data part overview

C. Discussion

In many medical incidents, the referring doctor, in order to make correct diagnosis, needs to know more data for the patient's state, than those provided by the acquired measurements. Data such as patient's demographic data, mnemonic and medical history, patient's allergy state, patient's ancestry, etc. affect the correct treatment or the patient's handling. Depending on the patient's symptoms, different measurements of patient's Vital Signs must be taken e.g. for cardiac diseases an ECG is taken.

The total amount of data acquired during an incident, has diverse type and length, compared to another incident. This leads to the necessity of an adaptive protocol in order to minimize the required transmission time, the recovery time and finally the storage space.

The realization of this adaptive protocol has been achieved by the addition of some extensions to the SCP-ECG protocol [1][2], which handles a basic set of demographics data and also ECG measurements. The new protocol is referred as e-SCP-ECG$^+$ protocol. Paper in reference [5], presents a first version of the extended protocol e-SCP-ECG (inclusion of sections 200, 201, 202, 203), while the work presented here enriches that protocol and introduces the e-SCP-ECG$^+$ version, which includes new sections (204, 205), adds new tags in section 1 and makes some improvements to the previous version. The paper in reference [6] presents the state of the art of a platform where the new protocol is incorporated.

The data handled by the e-SCP-ECG$^+$ protocol, covers patient demographic data, ancestry data, profession data, mnemonic and medical history, a quick description of the incident, a first diagnosis, allergy state and measurements on ECG, SPO2, NiBP, TEMP, Heart Rate and CO2.

The new protocol can be used in a big variety of medical

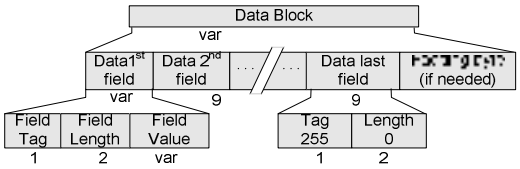

Fig. 5. - Overview of the data part holding the allergy data

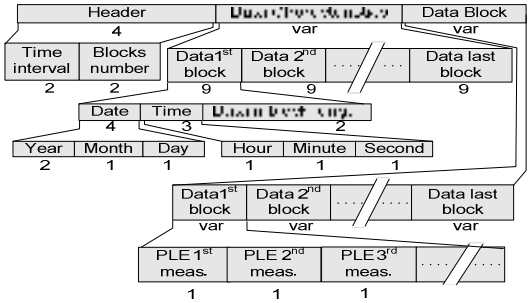

Fig. 6. Overview of the data part holding the SPO2 PLE data

incidents. The possibility to manage only the data that characterize each medical incident has the advantage of the minimal volume of data, which results in a high flexibility regarding its management and transmission rate.

This new protocol has been incorporated in a project with the collaboration of several central hospitals in Greece [6].

The real world operation phase will start in a few months. During this phase the thoroughness of the protocol will be evaluated.

D. Conclusion

Using the SCP-ECG standardization as a reliable protocol on patient and ECG data handling and communication, we have appended some tags and sections, enhancing it. As a result, we defined a protocol, which can be used in a big variety of medical incidents. The management of the data that are related to the treated medical incident leads to the minimal possible volume of data, which results in a high flexibility regarding its management and transmission rate.

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