Enhancements on SCP-ECG protocol for multi vital-sign handling

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Abstract: - The Standard **C**ommunication **P**rotocol for **E**lectro**C**ardio**G**rams (SCP-ECG) is used for the ECG data communication and handling. This paper presents an enhancement of SCP-ECG, which makes possible the transmission of more vital signs (apart ECG data), such as Oxygen Saturation (SPO_2), Pulse Rate, Temperature, Non Invasive Blood Pressure (NiBP) and Carbon dioxide (CO_2). The enhanced protocol has been utilized in the design and development of a prototype medical information network. This medical network can be used to supply doctors not only with the current patient information, but also with information concerning patient's previous state. In that way, the network helps doctors to make a more accurate diagnosis.

Key-Words: - SCP-ECG, NiBP , SPO_2, CO_2, Protocol, Vital Signs, Electrocardiogram, Electrocardiography

1 Introduction

Vital Signs are a major component of patient care. Evaluating a patient's breathing, acquiring the electrocardiogram, assessing the heart rate, taking his temperature, determining the blood pressure, and obtaining a medical history represent a basic set of actions, which lead to useful medical data. This information is obtained from every patient a medical doctor encounter. In emergency cases (e.g. ambulance transportation[1]), acquisition of the above vital signs is the first care service offered to the patient. Without this information, the doctor may remain unaware of life threatening conditions that require him to provide specific treatment at the scene along with prompt transport to the appropriate treatment facility.

The SCP-ECG[2][3] protocol specifies the demographics format and ECG data and the rules for their interchange between digital electrocardiographs (ECG carts) and heterogeneous computer systems (hosts), as well as other computer systems, where ECG data can be stored. In that way the establishment of a network consisting of servers that belong to various health care providers is made possible. Through the network, in terms of using unique patient identification, the assurance of care continuity is possible, as every time a patient visits a health centre, all the historical data referring to him can be retrieved.

This paper presents an enhancement of the SCP-ECG protocol, which makes possible the transmission and handling of not only the patient's demographics and ECG data, but also of other vital signs (e.g. SPO2, CO2). The enhancement leads in the transmission of a set of valuable indications on patient's health state, provided that they come from devices compatible to this protocol. In this way, each doctor is provided with all necessary data to make a more accurate diagnosis.

2 Vital Signs and their meaning on human health

This section deals with the definition and usefulness of vital signs that are concerned in this paper.

Electrocardiography is the leading and most reliable method for non-invasive diagnosis and detection of coronary heart disease. Recording of voltage changes transmitted to the body surface by electrical events in the heart muscle, is used in order to give doctors, either a direct evidence of cardiac rhythm and conduction, or an indirect evidence of myocardial anatomy (size, wall thickness, e.t.c). Electrocardiography also provides data about the blood flow between the heart and the body, the functional state of the heart e.t.c. The recording of the voltage changes on the heart muscle is called electrocardiogram (ECG) and is acquired using a set of electrodes called "leads". Each lead has a specific placement on the human body. The data collected are represented as a set of waveforms.

Pulse oximetry offers a relatively inexpensive, simple and reliable means to monitor respiratory function in a wide variety of clinical areas, in

hospitals and the community. It is used to monitor patients who have actual or potential respiratory problems. Pulse oximetry measures oxygen saturation levels (SPO2) by monitoring the percentage of hemoglobin (Hb), which is saturated with oxygen as well as measuring heart rate (pulse rate). Oximetry may be used for 'spot checks' or a continuous measurement. Measurements should always be considered, taking into account all clinical data acquired about this person. A 'spot check' or single measurement of hemoglobin saturation might suggest respiratory problems. Therefore a continuous measurement gives more reliable results.

The Body Temperature is a critically important vital sign that often affects patient treatment decisions. The measurement is performed in order to find out whether the patient's temperature is over the normal values. In those cases, the patient has a fever. Most fevers are a sign of infection and occur with other symptoms. Abnormally high or low temperatures can be serious.

Blood is carried from the heart to all parts of human body in vessels, called arteries. Blood pressure is the force of the blood pushing against the walls of the arteries. Each time the heart beats, it pumps out blood into the arteries. Blood pressure is at its highest when the heart beats, pumping the blood. This is called systolic pressure. On the other side, when the heart is at rest, between beats, blood pressure falls. This is the diastolic pressure. Blood pressure is always given as these two numbers, the systolic (higher) and diastolic (lower) pressures. Both are important. High blood pressure - also called hypertension - is a major health problem in the world today. It is sometimes called "the silent killer" because it doesn't have any symptoms, yet it can be causing serious damage inside the body. It is a primary cause of stroke, heart disease, heart failure, kidney disease, and blindness. It triples a person's chance of developing heart disease, and boosts the chance of stroke seven times and the chance of congestive heart failure six times. Blood pressure is acquired with both invasive and non-invasive methods. The easier one is the non-invasive measurement (NiBP).

Capnography is the measurement of carbon dioxide (CO2) in respiratory gas. A capnograph displays a waveform of CO2. Capnography is an effective monitoring tool for intubation verification, monitoring adequacy of ventilation, detecting disconnection of breathing system or ventilator, monitoring conscious sedation, detecting effective cardiopulmonary resuscitation, monitoring ventilation of closed head trauma, assessing seizure conditions, evaluating bronchospasm and asthma, monitoring malignant hyperthermia, metabolic assessments.

3 A brief description of the SCP-ECG protocol

The Standard Communication Protocol for Computer-assisted Electrocardiography, version prEN 1064:2002 prepared by CEN/TC 251 (SCP-ECG)[2][3] was defined because of the necessity ECG devices produced by different manufactures to be able to communicate with computers through the same language[4].

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 (patient data, machine's manufacturer data, ECG waveform data, ECG measurements and interpretation results).

The contents of a SCP-ECG formatted file are structured as a set of sections. Each section holds different type of information than the other sections. Table 2 shows the data structure of the protocol.

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, or 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

4 Snapshots on applications design

This section presents a snapshot of the medical network that uses the proposed enhancements.

The SCP-ECG protocol was originally employed on the development of a SCP-ECG module[2] as an extension on a telemedicine platform we had developed for the Hellenic Telecommunication Organization (OTE)[6]. But the necessity of concurrent transmission and management on more data along with patient demographics and ECG waveforms, lead us to suggest and utilize some new information parts on the SCP-ECG protocol. The enhancement makes possible the transmission of vital signs, such as Oxygen Saturation (SPO_2), Pulse Rate, Temperature, Non Invasive Blood Pressure (NiBP), Carbon dioxide (CO_2).

The enhanced protocol, has been employed, on a new medical network, we have designed.
This network implements a 3-stage architecture.

- The first stage is responsible for the data acquisition and transmission to a reception center. In this stage, both patient demographic data and vital signs are acquired. The vital signs can be collected either by separate devices or using patient monitors. A notebook merges the demographic data and vital signs and transmits them to the reception station as an enhanced SCP-ECG file.
- The second stage includes rules and procedures on the data storage system to manipulate the database. In the reception center, the newly arrived files are archived in a database in order to be available on the network.
- The third stage includes user access to the application. It presents patient data and waveforms to the user and has an intelligent user-friendly interface that allows users to easily preview, manage, interrelate and manipulate any medical data. It also permits query over the entire medical network in order to collect historic references for a patient.

5 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 more vital sign data along with the ECG data. Therefore, new sections have been proposed to satisfy this requirement. According to the protocol specifications, section numbers 128 to 1023 are available for manufacturer specific sections.

So, according to the necessity for the transmission of the extra vital sign and other data we have assigned and used the following new sections:

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

Each new section follows the SCP_ECG protocol general sections format. So, each section consists of:

- A Section Identification Header
- A Section Data Part

5.1 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 Section Version Number of the Protocol
11-16	6 bytes Reserved for future use

The Section Data Part for the new sections has the following structure:

5.2 Section 200 (SPO2 – Pulse Rate Data)

This section contains measurements for oxygen saturation (SPO_2), and the corresponding pulse rate. Because of the possibility of interrupted data acquisition, measurements can be stored as data blocks.

5.2.1 If present, the section shall start with a "Section ID Header" as defined in paragraph 5.1.

5.2.2 The data part header contains global settings for the measurement of SPO_2 and pulse rate. It is formatted as:

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

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

Byte	description
	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
	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 data block length

5.2.4 The data block contains the measured data for SPO_2 and pulse rate.

Byte	description
1	1st value for SPO_2
2-3	1st value for pulse rate
4	2nd value for SPO_2
5-6	2nd value for pulse rate
etc	

5.2.5 An overview of the data part of this section is presented below:

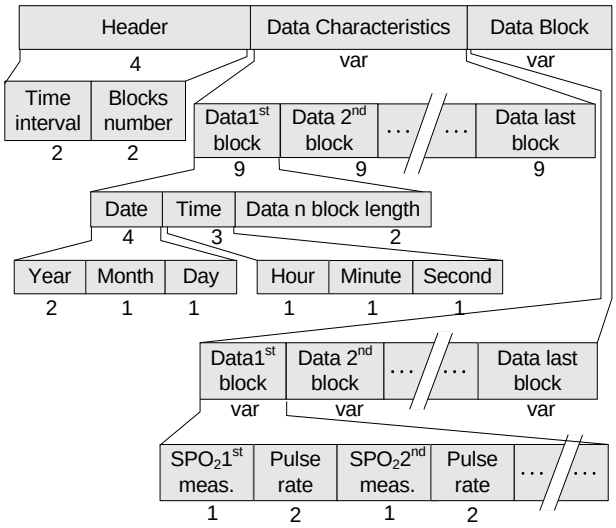

Fig. 1 - Overview of the data part holding the SPO_2 and pulse rate data

5.3 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

5.3.1 If present, the section shall start with a "Section ID Header" as defined in paragraph 5.1.

5.3.2 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
2	units 0 = Celsius degrees 1 = Fahrenheit degrees

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

5.3.3.1 If the measurements consist of distinct values, the remaining header is the following:

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

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

Byte	description
3	Date of acquisition
1-2	year in four-digit format
3	month in two-digit format
4	day in two-digit format
4-6	Time of acquisition
5	hours in two-digit format
6	minutes in two-digit format
7	seconds in two-digit format
7-8	time interval between measurements in microseconds ($1*10^{-6}$s)
9-10	binary: the number of temperature measurements

5.3.4 The detailed information for each measurement is as follows

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

Byte	description
	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
	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-…	the same as bytes 1-9 for the rest of the measurements.

5.3.4.2 In the case of 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.

5.3.3 An overview of the data part of this section is presented below:

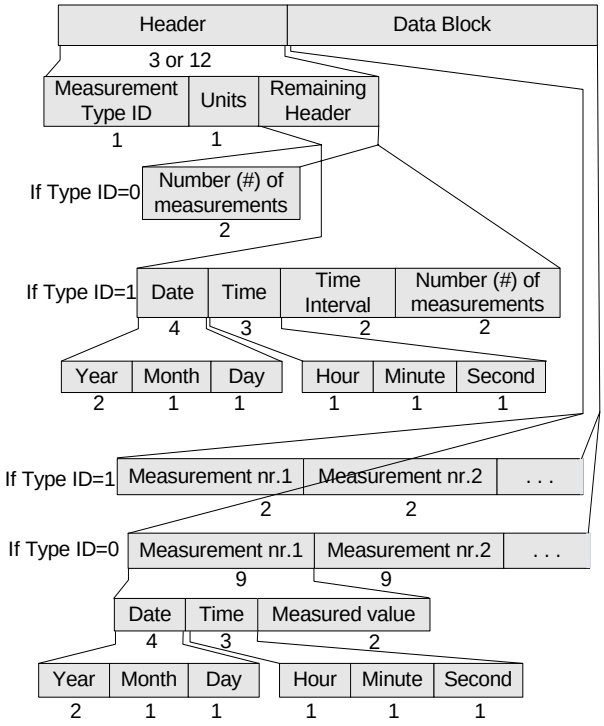

Fig. 2 - Overview of the data part holding the temperature data

5.4 Section 202 (Non-Invasive Blood Pressure NiBP)

This section contains measurements for the non-invasive blood pressure. Those measurements can be performed once or at specific intervals.

5.4.1 If present, the section shall start with a "Section ID Header" as defined in paragraph 5.1.

5.4.2 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
	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
	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	Time interval between measurements in microseconds ($1*10^{-6}$s)
9-10	Number of measurement blocks

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

Byte	description
1-2	1st value for systolic blood pressure
3-4	1st value for diastolic
5-6	2nd value for systolic
7-8	2nd value for diastolic

etc

5.4.4 An overview of the data part of this section is presented below:

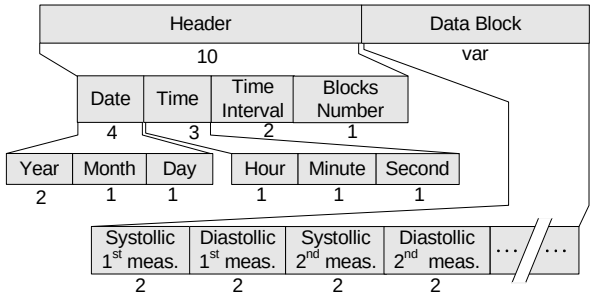

Fig. 3 - Overview of the data part holding the systolic - diastolic blood pressure data

5.5 Section 203 (Capnography CO_2 Data)

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

5.5.1 If present, the section shall start with a "Section ID Header" as defined in paragraph 5.1.

5.5.2 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
	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
	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 ($1*10^{-6}$s)
10	Units:

1 mmHg
2 Torr
4 %
5 kPa

10-11 Number of measurements

5.5.3 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	

5.5.4 An overview of the data part of this section is presented below:

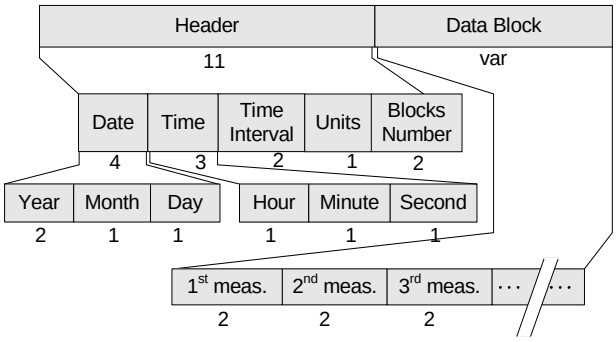

Fig.4 - Overview of the data part holding the carbon dioxide data

6 Discussion

The designed and developed service with the enhancements on the SCP-ECG protocol makes possible the easy transmission of not only the patient's demographics and ECG data but also of data for SPO2, CO2, Temperature, Pressure and pulse rate. The enhancement acts as a complement, which leads in the transmission of a "file" including all the valuable indications on patient's health state.

A doctor using a workstation that belongs to a medical network, which implements the enhanced protocol, can receive electrocardiogram waveforms from devices compatible with the SCP-ECG protocol, constructed by various manufacturers. He is also able to receive more vital signs such as SPO2, CO2, Temperature, Pressure and pulse rate from devices compatible with the enhanced protocol. Processing of waveforms, modification, storage, query, and retrieval of files are also supported functions. The adopted protocol with its structured data format also permits the query of patient health records stored in various health care providers, belonging on the medical network, in order to guarantee the continuity of health care.

7 Conclusion

Using the SCP-ECG standardization as a reliable protocol on patient and ECG data handling and communication, we have appended some sections, enhancing it. The new form is compatible with its ancestor, but it can handle more vital sign data.

Using the modern communication networks, the establishment of a medical network consisting of servers that belong to various health care providers is possible. Each health provider stores electronic patient records. The exchange of this information is made possible through the usage of the above protocol. So, using unique patient identification the assurance of continuity of care is possible. By means of a continuously updated list with health care providers compliant to the enhanced SCP-ECG protocol, every time a patient visits - physically or using the telemedicine network - a health centre, all historical data referring to him (demographics and examination data) can be retrieved. This process provides doctors information on the previous state of the patient and helps them to make a more accurate diagnosis.

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