e-SCP-ECG$^+$v2 Protocol: Expanding the e-SCP-ECG$^+$ Protocol

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Abstract. Nowadays, the fast-growing technology market for sensors and smart devices allows anyone to constantly monitor important vital parameters, like electrocardiogram (ECG). Mobile health systems typically employ data transmission to the premises of the health service provider via appropriate telecommunication protocols, which often consider only vital parameters. However, these parameters are likely to vary, depending on each person's exercise, psychological condition, habits, environmental conditions and many other factors. Thus, it is necessary to utilize a protocol that is able to carry additional data concerning factors that are tightly connected with the quality of vital sign measurements. This paper proposes an extended version of the e-SCP-ECG$^+$ protocol, mainly used for ECG data transmission, in order to include several types of information that affect the quality of the obtained signal, as well as the diagnosis process. The aim is to offer medical experts with an enriched clinical view of the patients so as to diagnose a medical incident more accurately.

Keywords: e-SCP-ECG$^+$ · Vital signs · Health communication protocol

1 Introduction

Recent advancements in several areas of consumer electronics and computer science, such as wearable and mobile networked devices, wireless sensors and sensor networks, pervasive computing and artificial intelligence have massively benefited mobile health and Ambient Assisted Living (AAL) systems. Such systems include a wide range of applications that span from health monitoring and medication compliance to cognitive assistance and activities of daily living facilitation, as well as location tracking and social inclusion. Health monitoring of individuals is the most prevalent application category aggregating numerous research prototypes as well as commercial systems and applications. Being able to wirelessly monitor health status without spatiotemporal restrictions is a significant factor for an increased quality of life. Especially, older adults and people with chronic health problems require constant monitoring and care

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provision driving the need of technology enabled solutions that provide adequate support to allow them to stay in their domestic environment for longer while retaining their safety, independence and autonomy.

Health monitoring mainly concerns continuous measurement of human physiological parameters, in order to visualize measured data, evaluate the medical status of an individual, perform specific medical care actions (e.g. produce an alert to a physician or relative) based on the identified medical status, or store data for further analysis (e.g. recognition of abnormalities in heart function through a 24–48 h electrocardiogram (ECG) analysis). A specific group of physiological parameters called vital signs consists of the most important signs that indicate proper human body function (i.e. ECG, pulse oximetry, heart rate, blood pressure and body temperature), which are the most commonly monitored health parameters.

The last decades various Health Telemonitoring Systems (HTS) have been proposed in the literature. The first step in these systems is to acquire a number of relevant data (based on each system's objectives and requirements) using appropriate sensing devices. Conventional telemedicine systems enable live or asynchronous transmission and display of measured data from a remote place to centrally located physicians primarily for diagnostic purposes. More sophisticated mobile and pervasive health systems employ signal processing techniques and data analysis algorithms in order to autonomously assess one's health status. The next step of the latter systems is to employ decision support functions to reason over the services to be delivered. In the majority of these systems, sensed data usually have to be transmitted in a central location for storage, management and visualization.

However, capturing purely health data in many cases is not enough. There are many other factors that interfere with the measured values and have a direct relation to health status assessment and treatment provision processes. For instance, acceleration data is also used to identify whether an individual is doing some exercise affecting ECG measurements. On the other hand, context information is equally important either for delivering appropriate healthcare services (e.g. location data for on-point care), or getting to understand influencers of several disorders (e.g. anxiety and mood disorders), while other types of information such as lifestyle and habits (e.g. sleep patterns, exercise, etc.) may also contribute to an enhanced clinical view of an individual. Continuous development of sensors market and smart devices, offers the ability to collect easily more and more useful information concerning health, context and personal data. The increased emergence of commercial off-the-shelf eHealth devices and HTS facilitate collection and transmission of various types of data previously hard to acquire, such as emotional state, habits and environmental coefficients, data which are either directly or indirectly relate to one's overall health status (i.e. physiological, psychological, mobility, etc.).

Many protocols have been proposed for biosignal collection and transmission, especially concerning ECG. A widely used protocol is the Standard Communication Protocol for Computer-assisted Electrocardiography (SCP-ECG) [1, 2], which is used for the ECG data communication and handling. As mentioned above, there is a significant amount of occasions that an expert needs more information about an individual than sole ECG recordings to make a more accurate diagnosis. Moreover, there are many factors that are tightly connected with the quality of ECG measurements, which in some cases may completely alter the acquired signals' characteristics and lead to imprecise diagnosis.

A previous research led to the construction of an extended protocol named e-SCP-ECG+ [3], which used the flexible structure of SCP-ECG to augment existing sections for management of additional information. The enriched protocol considered new sections for vital, context aware and patient-centric data. Vital signs sections comprised of at least six biosignals (ECG, NiBP, SPO_2, Temp, CO_2 and Pulse Rate), as well as plethysmographic (PLE) data for SPO_2 measurement. The context aware sections contain information about geo-location and altitude. Finally, the patient-centric information sections incorporate data about allergies, blood group, environmental elements (residence, work, etc.), and personal constraints (e.g. interdiction of blood-transfusion for religious reasons).

Aiming to address the introduction of all these new types of information in conjunction with the need of obtaining more information on factors interfering with ECG measurements to increase diagnoses' accuracy, in this paper we propose some further extensions to the e-SCP-ECG+ protocol, trying to enrich the patients' available data a medical expert is going to evaluate. The latest version of the protocol has included in its structure new sections for data collected by sensing devices that monitor activity, and also data about patient drug usage, body morphology, life time habits, acts before the test, mental state and other. The extra data could be useful to an expert that is called to evaluate medical data collected by a nonprofessional in an unknown environment.

2 Factors Affecting the Vital Sign Quality and Reliability

When a patient undergoes an examination in a hospital, the medical stuff follows standard procedures in order to have correct tracing quality and reliable results. But when an examination is done outside a hospital setting, at regional medical centers or by a private physician, a series of information may not be taken into consideration resulting in inaccurate medical status assessments. Alike, in wireless health monitoring systems data are collected in real world dynamically changing non-controlled settings and biosignal vital sign transmission has to be coupled with additional information (e.g. location, activity, etc.) in order to reach a valid diagnosis and deliver better healthcare services. In all the aforementioned scenarios, acquisition of various additional data about the examined patient and the ambient environment is a necessity. There exists a variety of researches [4, 5], which mention important factors that can affect vital sign measurements. Sex [6–8], ethnicity, mental state [9, 13] and emotions [10–12], life style [14], food and drink consumption [15, 16], blood analysis indexes [5, 16, 17], medication [16, 18, 19] and environmental interactions [20, 21] are some of these.

In this context, in our current work, we extended the e-SCP-ECG+ protocol inserting new sections for context aware and patient-centric data. The context aware section comprises of data from accelerometers, magnetometers and gyroscope devices that are able to provide information concerning the current activity, specific body movements, potential falls and current location. The patient-centric information incorporates data about patient's anatomy (morphology), pregnancy (if patient is woman), food or drink the patient consumed before the vital sign acquisition, smoking, blood examination results, drugs and mental state among others.

Using the extra information, a medical expert has a more integrated picture of the examined patient resulting in a more reliable diagnosis, especially when artifacts are involved in the collected data.

3 Additions to the e-SCP-ECG$^+$ Protocol

The Standard Communication Protocol for Computer-assisted Electrocardiography, version prEN 1064:2002 (SCP-ECG) [1, 2] was defined in order for ECG devices produced by various manufactures to be able to communicate with computers through a common language.

The SCP-ECG covers first the connection establishment between digital electrocardiographs (ECG carts) and heterogeneous computer systems (hosts) and second the rule definition for the cart to host or cart to cart data exchange (patient data, device's manufacturer data, ECG waveform data, ECG measurements and interpretation results).

The contents in a SCP-ECG formatted file are structured as a set of sections. Each section holds different type of information than the other sections. The SCP-ECG protocol defines section ID numbers 0 through 11 in its structure, reserves section numbers 12 to 127, as well as numbers above 1023, for future use. Section ID numbers 128 through 1023 are left for manufacturer-specific information.

A previous paper presented an extension of the SCP-ECG protocol named e-SCP-ECG$^+$. That extension introduced novel sections into SCP-ECG structure for transferring data for positioning, allergies and five additional bio signals: noninvasive blood pressure (NiBP), body temperature (Temp), Carbon dioxide (CO_2), blood oxygen saturation (SPO_2) and pulse rate. It also introduced new tags in existing sections for transferring comprehensive demographic data.

The proposed e-SCP-ECG$^+$v2 protocol comes to enrich the e-SCP-ECG$^+$ protocol assigning the following new sections:

- Section-208 for accelerometer data,
- Section-209 for gyroscope data,
- Section-210 for magnetometer data,
- Section-211 for drugs data,
- Section-212 for patient status data,

All the sections of the e-SCP-ECG$^+$v2 protocol adopt the general sections format of the SCP-ECG protocol which are constituted of two parts, the section Identification Header and the section Data Part. The section Identification Header part is used without any modification. Bellow in Fig. 1 the structure of the Data Part (DP) of the new sections is analyzed. Each field contains a specific number of bytes as indicated in Fig. 1.

The Section-208 DP (**Fig.** 1) handles accelerometer data (triples of x-axes, y-axes and z-axes). The accelerometer data can be acquired either through using a permanent rhythm (mt = 1) or asynchronously (mt = 0). It consists of the "DP Header", the "Data Parameters", and the "Data Block". The "DP Header", contains the measurement type (mt), the units and the range. If mt = 1, "Data Parameters" records Date, Time, time

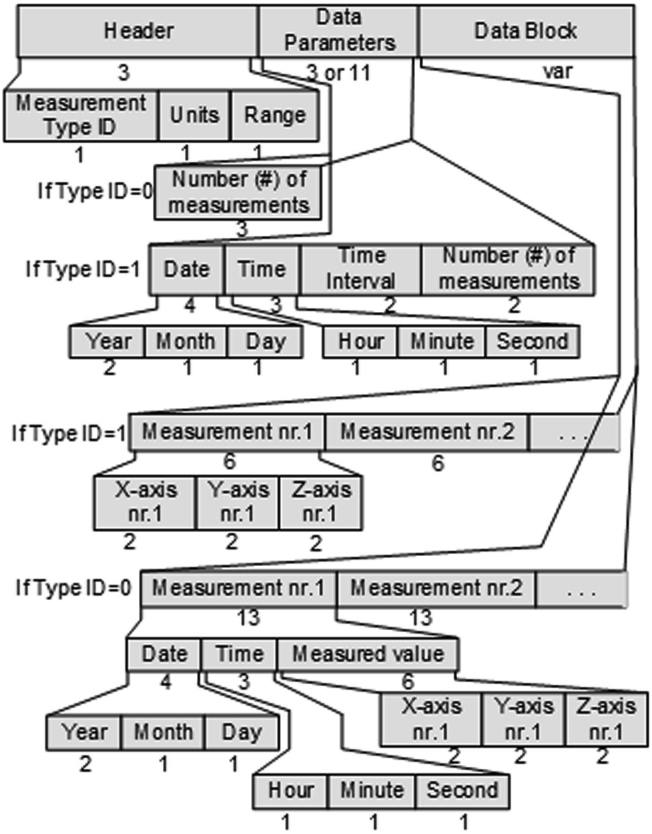

Fig. 1. Overview of the data part handling the accelerometer data.

interval and number (#) of measurements. If mt = 0, "Data Parameters" records only the number (#) of measurements. The "Data Block" records the captured triples of measurements. If mt = 1, "Data Block" keeps the successive recordings of the periodically acquired triples of values. If mt = 0, "Data Block" keeps successive recordings of distinct measurements (Date, Time and triples of values).

The Section-209 DP (**Fig.** 2) handles gyroscope data (triples of x-axes, y-axes and z-axes). The gyroscope data can be acquired either through using a permanent rhythm (mt = 1) or asynchronously (mt = 0). It consists of the "DP Header", the "Data Parameters", and the "Data Block". The "DP Header", contains the measurement type (mt), the units, the sensitivity and the range. If mt = 1, "Data Parameters" records Date, Time, time interval and number (#) of measurements. If mt = 0, "Data Parameters" records only the number of measurements. The "Data Block" records the captured triples of measurements. If mt = 1, "Data Block" keeps the successive recordings of the periodically acquired triples of values. If mt = 0, "Data Block" keeps successive recordings of distinct measurements (Date, Time and triples of values).

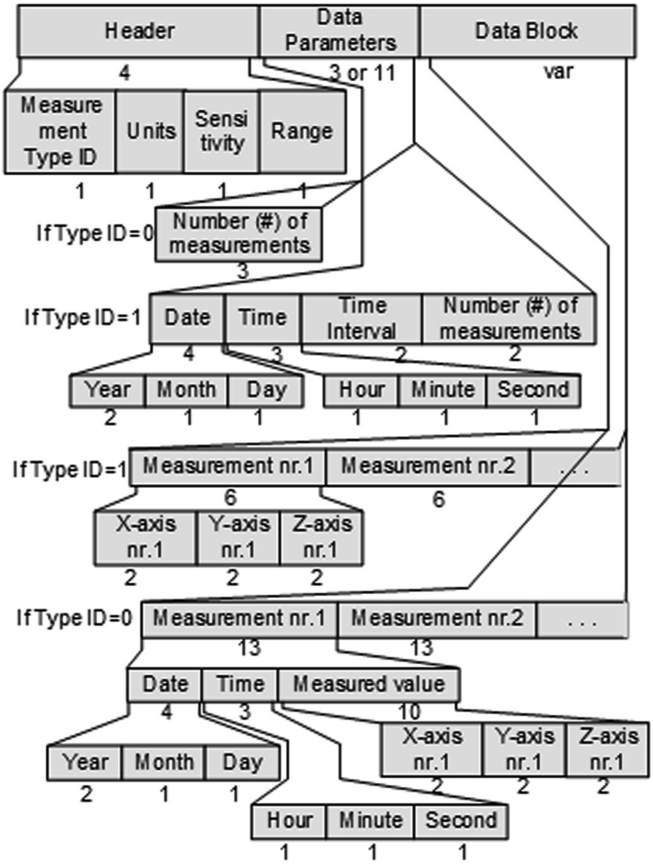

Fig. 2. Overview of the data part handling the gyroscope data.

The Section-210 DP (**Fig.** 3) handles magnetometer data (triples of x-axes, y-axes and z-axes). The magnetometer data can be acquired either through using a permanent rhythm (mt = 1) or asynchronously (mt = 0). It consists of the "DP Header", the "Data Parameters", and the "Data Block". The "DP Header", contains the measurement type (mt), the units and the accuracy. If mt = 1, "Data Parameters" records Date, Time, time interval and number (#) of measurements. If mt = 0, "Data Parameters" records only the number (#) of measurements. The "Data Block" records the captured triples of measurements. If mt = 1, "Data Block" keeps the successive recordings of the periodically acquired triples of values. If mt = 0, "Data Block" keeps successive recordings of distinct measurements (Date, Time and triples of values).

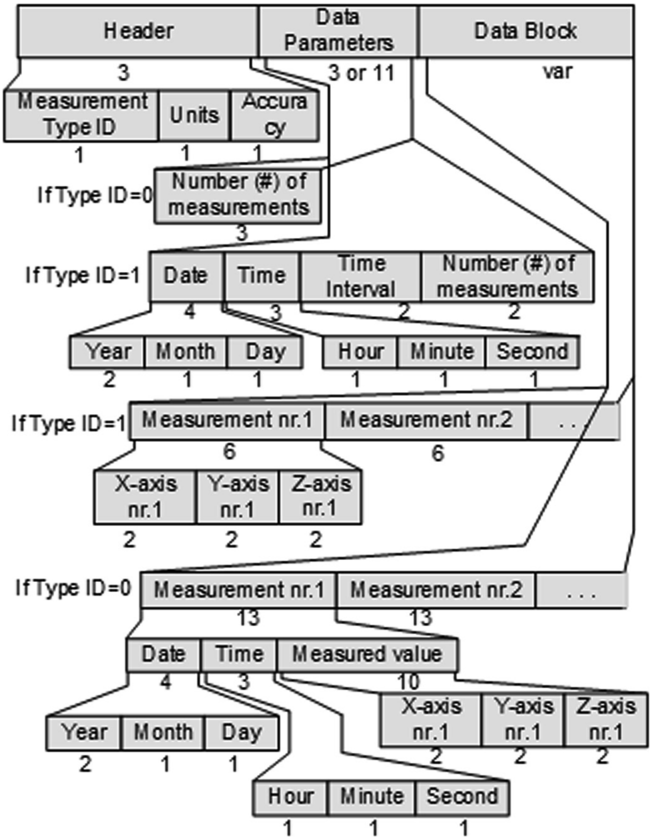

Fig. 3. Overview of the data part handling the magnetometer data.

The Section-211 DP (**Fig.** 4) handles data about drugs which the patient takes. It registers one record per each drug containing: Active substance code, commercial drug name, dosage, usage duration, comments on reactions.

The Section-212 DP (**Table** 1) handles data about patient status. This section includes information related with factors affecting the measured values of the collected biosignals and should be considered when determining patients' health status. This information concerns potential pregnancy (if patient is woman), the weight distribution on a patient's body, foods, drinks or smoking before the biosignal acquisition, usage of abused substances, hematology indexes (especially Potassium, Calcium, Sodium and Magnesium), acts before the measurement acquisition and comments on the person's psychological state.

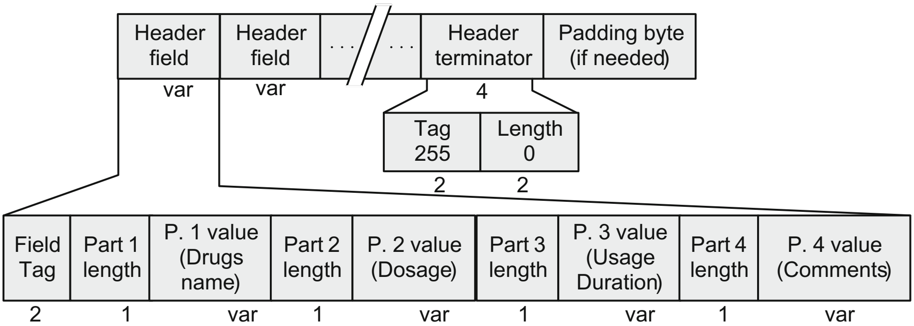

Fig. 4. Overview of the data part handling the drugs data.

Table 1. Definition of data part of Section-212 (Patient status)

Tag	Length	Value (Parameter Data)			
1	**1**	**Consumption** (Binary). Has the following format:			
		Bit	Contents		
		0	Alcohol	Set = Yes	Reset = No
		1	Coffee	Set = Yes	Reset = No
		2	Smoking	Set = Yes	Reset = No
2	**length**	**Consumption – other substances** (Text characters) This field permits free text comments about the consumption of other substances			
3	**1**	**Pregnancy** (Binary). Has the following format:			
		Bit	Contents		
		0	pregnant	Set = Yes	Reset = No
		1	1 fetus	Set = Yes	Reset = No
		2	2 fetus	Set = Yes	Reset = No
		3	3 fetus	Set = Yes	Reset = No
4	**1**	**Acts before examination** (Binary). Has the following format:			
		Bit	Contents		
		0	running	Set = Yes	Reset = No
		1	climbing stairs	Set = Yes	Reset = No
		2	quick stepping	Set = Yes	Reset = No
5	**1**	**Weight distribution** (Binary). Has the following format:			
		Bit	Contents		
		0	Physiological	Set = Yes	Reset = No
		1	Chest region	Set = Yes	Reset = No
		2	Belly region	Set = Yes	Reset = No

(*continued*)

Table 1. (*continued*)

<table>
<tr><th>Tag</th><th>Length</th><th colspan="4">Value (Parameter Data)</th></tr>
<tr><td rowspan="5">6</td><td rowspan="5">1</td><td colspan="4">Hematology indexes (Binary). Has the following format:</td></tr>
<tr><td><u>Bit</u></td><td colspan="3"><u>Contents</u></td></tr>
<tr><td>0</td><td>Potassium</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>1</td><td>Magnesium</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>2</td><td>Calcium</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td></td><td></td><td>3</td><td>Sodium</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td rowspan="16">7</td><td rowspan="16">2</td><td colspan="4">Emotions (Binary). Has the following format:</td></tr>
<tr><td><u>Byte</u></td><td colspan="3"><u>Contents</u></td></tr>
<tr><td rowspan="8">1</td><td>Bit 0 Fear</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 1 Anger</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 2 Sadness</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 3 Joy</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 4 Disgust</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 5 Surprise</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 6 Trust</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 7 Anticipation</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td rowspan="6">2</td><td>Bit 0 Shame</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 1 Kindness</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 2 Pity</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 3 Indignation</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 4 Envy</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>Bit 5 Love</td><td>Set = Yes</td><td>Reset = No</td></tr>
<tr><td>8</td><td>length</td><td colspan="4">Mental state (Text characters)
This field permits free text comments about the psychological state of the patient.</td></tr>
</table>

4 Discussion and Concluding Remarks

The biosignal waveforms collected from a subject are sometimes influenced by physiological, technical pathophysiological, emotional and environmental factors. Many studies from different researchers have tried to prove the role of each factor and its impact on vital sign acquisition and accurate diagnosis. For example, changes in a person's mental state can be reflected on the quality of ECG. There are inner emotions such as joy, fear, anger, hope, etc., and outer emotions such as crying, laughing, sweating, etc., which differently affect the output signal of ECG. Environmental factors such as magnetic fields from electrical wires or machines, location and physical conditions (e.g. humidity, temperature, etc.) also play a crucial role in the quality of the obtained ECG. Other factors interfering with ECG recordings include consumption of food or drink, smoking, body's fatigue immediately before the measurements acquisition, while many drugs and substances influence the ECG waveforms. Morphology of the torso, body mass index and pregnancy, as well as changes of the body position and posture can also have significant effects on the collected data.

So, complementing ECG measurements with a group of other relevant information about a patient is deemed essential for a referring doctor to better evaluate collected data, especially in cases where the data are acquired by devices operated by non-technical stuff. Towards this direction, the e-SCP-ECG$^+$v2 protocol integrates different types of information about a person along with his medical data in a single file. As a result, the newly defined protocol can be used in a big variety of medical oriented applications, providing medical experts with a wider dataset to base their diagnosis and choose upon the treatment to be followed.

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