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Information Exchange Protocol for Mobile Heart Monitoring System

Thomas Chee Tat Ho and Xiang Chen, *Senior Member, IEEE*

Abstract—**The amount of information that can be gleamed from portable medical measuring apparatus is tremendous. Many portable medical apparatus manufacturers in the world are performing their own research and development to extract information. However, the data structure and protocol for the conveyance of the extracted information is left to the discretion of the manufacturers. This is because there is a lack of agreement on a standard data structure protocol format between such medical apparatus manufacturers to conform to a common communication and data transport protocol. Hence valuable extracted knowledge is left dispersed among these communities. This paper proposes an approach to a dynamic medical information exchange protocol to increase the interoperability of real-time medical measurements extracted by devices from medical industry manufacturers.**

I. Introduction

ALTOUGH there are several existing protocols[1]–[3] that catered to information exchange amongst heterogeneous devices, they are still insufficient when dealing with information exchange amongst heterogeneous ubiquitous mobile devices; especially when the ubiquitous mobile device is receiving information from several other external portable medical measuring apparatus. As the protocols [2], [3] were designed with XML as the underlying information carrier, they are restricted by their own limitations for bulky data files transfer as well as the high overheads they yield for frequent small data files transfer.

Solutions [2]–[4] designed to offer informational interoperability for enterprise systems cannot simply be ported and be used on mobile ubiquitous devices. And for that matter, such protocols may not be appropriate for use to convey proprietary medical information extracted from the portable medical devices.

As tele-monitoring with ubiquitous mobile devices becomes more common [5]–[7] and the sharing of medical information becoming more beneficial [8], we propose to devise and implement a protocol with a message generation wrapper for rapid real-time medical information exchange between mobile phones and servers. The Continua Health Alliance [9] is working on a standard for manufacturers to conform. Coincidentally, we are also proposing an augmenting approach to bridge the data structure conformity divide in the current portable medical apparatus manufacturer community, but we strive not to homogenize the manufacturers' use of protocols.

Thomas C.T Ho is with The Institute for Infocomm Research, Singapore (email: ctho@i2r.a-star.edu.sg phone: +6564082633).
X. Chen is with The Institute for Infocomm Research, Singapore (email: xchen@i2r.a-star.edu.sg phone +6564082638)

II. The Problem and The Current Requirements

A. The Problem

Currently, there are many companies that developed their own tele-health monitoring devices. They developed devices that tele-monitor different aspects of health and in the essence of their individualistic development also produced a unique, intrinsic and proprietary method to convey medical information from the device to a viewable context on the computer. No doubt, it would be good to have all the devices work in unison to provide the most coverage of monitoring. However, there is no way to share this valuable information with the rest of the medical community; unless of course each entity that wants to view the information also purchased the same device as the user such that the information decoder is obtained. Moreover, additional bandwidth is wasted decoding the individualistic medical information from the monitoring devices.

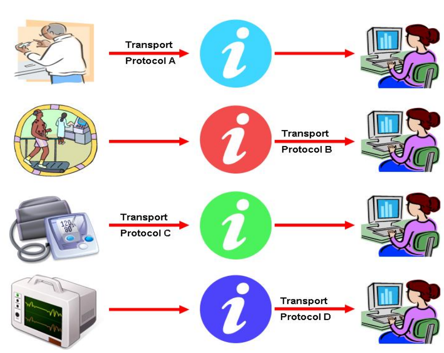

Fig 1. Non-interoperability of medical information leading to wastage of bandwidth decoding individualistic medical information.

This also made storage and access by other third party users difficult. Moreover, the notion of data synchronicity with regards to time is also lost. At the most, users of the data can only rely on the timestamp of the data, assuming that the clocks on the devices were all synchronized if they had one.

Hence, in this paper we proposed to consolidate all the devices onto a common mobile platform before they are to be transmitted to repositories for usage. However, even in this case the current information transport protocol is still lacking. The current standards do not consider the power consumption of the equipment used to act as an information conveyor. Likewise, ubiquitous wireless equipments do have a more restricted bandwidth compared to internet wire-connected equipments. Finally, current standards do not account for packet loss due to fading, shadowing and other radio effects. Since we are dealing with medical information transfers, data reliability is one of the important aspects.

B. Current Requirements

We propose that in order to promote the interoperability of medical information, obtained from portable medical devices, the data flow should be as described in Fig 2 with information shared amongst many users.

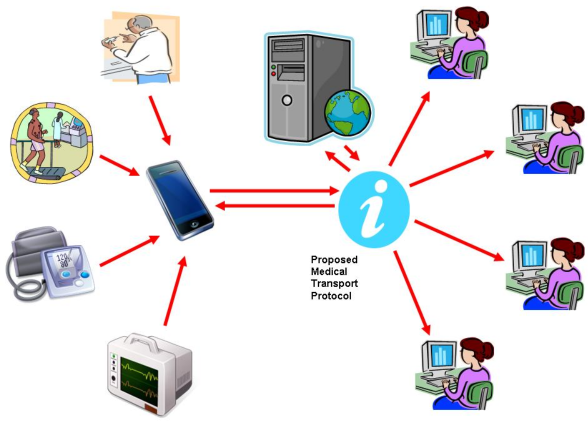

Fig 2. Interoperable medical information exchange protocol.

And also with the most important requirement, this medical information exchange protocol must guarantee a very high percentage of data reliability so that physicians, clinician and related medical staff will not conclude the wrong diagnosis or prognosis based on the tele-medical data.

III. METHODOLOGY

In our method, the amount of data to be forwarded is adaptive to the changing circumstances, with the special packetization of the information. The information transmitted may or may not be co-related. If the information is co-related, then this proposed approach offers a feature of synchronicity for co-related time sensitive data. And in the event of packet loss, the proposed approach is able to backtrack and resend the lost packet to complete the data. Its specialized information management enables it to handle information from multiple sensors of the same or different types. The information from all the devices will be collaborated together to function as one individual stream. Plus it also allows instantaneous detection of any sudden loss or malfunction of the multiple sensors at no extra data costs. Continuous data information stream can be transmitted in real time with minimal latency. Since it allows for more flexible structural definition of the data in the packets, no-starvation of information will occur at the server end. This proposed approach is being used in our current clinical trial system in our local hospital.

A. Protocol Packet Structure

The packet structure is the crux of the proposed approach. Generally, it is a structure of information preceded by definitive tags that will describe the type of the information. It only requires a tag at the beginning, unlike XML where the information is enclosed within a pair of tags.

For instance, let's consider a situation where there are 5 different types of information that is required to be forwarded from the mobile phone to a data center:

1) Conditions
2) Heart Rate – Time sensitive data that is co-related to Accelerometer
3) Accelerometer – Time sensitive data that is co-related to Heart Rate
4) Measurements
5) ECG

Assuming if all data are available at the point of packetization, then the packet would look like Fig 3.

Seq 4 Bytes	**ID** 11 Bytes	**Conditions** 12 Bytes	**Heart Rate** 7 Bytes	**Accelero meter** 7 Bytes	**Measure ment** 7 Bytes	**ECG** n Bytes

Fig 3. A packet of containing 5 types of data

Within each individual segment in the packet, the tags and

Seq: Sequence Number

Running Sequence Number 000-999 4 Bytes	

ID: Identification

Header 3 Bytes	**ID** 8 Bytes

Conditions:

Header 3 Bytes	**Data** 3-9 Bytes – can include multiple conditions separated by delimiters

Heart Rate:

Header 3 Bytes	**Data** 4 Bytes

Accelerometer:

Header 3 Bytes	**Data** 4 Bytes

Measurements:

Header 3 Bytes	**Data** 4 Bytes

ECG:

Header 3 Bytes	**Data** n-3 Bytes

Fig 4. Data sequence and size

the data would be packed in the manner as shown in Fig 4.

In a packet under our proposed approach, there is no definitive set of data tags. Tags are packed into the packet if and only if the corresponding data is available at the point of packetization else it will be counted as extra overheads that the packet must bear. In XML, a null value must be inserted if the data is unavailable. Let us now consider another where the data type condition is not available. Our proposed approach would produce a data packet like Fig 5.

Seq 4 Bytes	**ID** 11 Bytes	**Heart Rate** 7 Bytes	**Accelerometer** 7 Bytes	**ECG** n + 12 + 7 Bytes

Fig 5. Dynamic packetization offered by proposed approach in absence of 1 data type - conditions

The freed bytes will be utilized to transport data that is voluminous in nature like electrocardiogram (ECG). This is an information protocol catered especially to the medical community for the rapid exchange of information across different platforms. This protocol allows for dynamism in the many types of information. For instance, if a device is transmitting information like ECG, heart rate and movement intensity, it will transmit the information immediately when it is available.

In our proposed approach, except for the first set of tags and data that is incidentally the packet sequence number and packet-owner identifier, there is no ordering in the information. All information is packed on a first come first served basis. Hence, the order of the information arrival is also preserved. Unlike in XML where the order of the information arrival is lost and the tree-structure of XML may become too complicated if the information has many deep branches.

It is still possible to preserve data that has synchronicity implications with data from other sensors. This is done by specifying the time-synchronicity of the data tuple before the packet engine is in operations. If at a certain time T, only ECG and QT are available, it will then compile the information based on these 2 types of information. Since both heart rate and movement intensity are co-related and time-sensitive to each other, one is constraint by the other. Hence, both are not forwarded as shown in Fig 6.

Seq 4 Bytes	**ID** 11 Bytes	**Measurement** 7 Bytes	**ECG** n + 12 + 7 + 7 Bytes

Fig 6. Constraint restricted data

The proposed structure is scalable as more and more information needs to be conveyed between mobile phones and servers. More segments can be added into the packets. This information can be from multiple types of monitoring device contributing different type of information to a single mobile phone. If the total information exceeds the packet limit size then the last byte of the segment would indicate if the next packet should be a continuation of this currently packet as shown in Fig 7.

Seq 4 Bytes	**ID** 11 + a Bytes	**Heart Rate** 7 Bytes	**Accelero meter** 7 Bytes	**SpO2** n - 33 – a Bytes	**Chain** 1 Byte

Seq 4 Bytes	**Measure ments** 7 Bytes	**Blood Pressure** b Bytes	**ECG** n-b-11 Bytes

Fig 7. Scalable dynamic addition of new data from new sensors with 'a' as the additional space needed to encompass all the device IDs

In this case the packet header as shown in Fig 8 will also include the ID of the device the different type of information is coming from. The ID information will also adjust to include the IDs of the devices and the priority of the information. Given a priority, means how much more space will be allocated to the information in the packet. More instances will be transmitted compare to lower priority information.

This serves as a bonus indicator of how many devices are in the correct working state. Due to this, the proposed approach can also easily scale up to catering multiple devices of the same type as shown in Fig 9.

Header 3 Bytes	**ID** 8 Bytes	**Device IDs** c Bytes	**Device Priority** D Bytes

Header 3 Bytes	**Device ID** 1 Byte	**Data** m Bytes

Fig 8. Breakdown of ID segment for inclusion of new sensors with

Seq 4 Bytes	**ID** 11 + a Bytes	**Heart Rate** f Bytes	**Accelero meter** g Bytes	**Chain** 1 Byte

Seq 4 Bytes	**ECG** n Bytes

Fig 9. Multiple devices of the same type contributing more information to 1 handphone

Header 3 Bytes	**IDS** Number of devices x 1 Bytes	**Heart Rate** Number of devices x 4 Bytes

Fig 10. Heart sub-structure catering to multiple devices

For the above where heart and accelerometer are co-related the number of data values in heart rate should corresponds to the number of values in accelerometer to some degree. Hence their structure would look in Fig 10 and if they are non-related it would look like Fig 11.

Header 3 Bytes	**ECG 1 ID** 1 Byte	**ECG 1** x Bytes	**ECG** Y Bytes	**ECG K ID** 1 Byte	**ECG K** z Bytes

Fig 11. ECG sub-structure

No standard rule exists for the length of the packet. It should be a size that the real-time mechanism is maintained with no flooding of the network with small packets. The decoding complexity is minimal. Since each data is tagged with a header, the decoder need only read the header to decode the meaning of the information coming next. Therefore, the decoding is complex than the encoding.

This protocol ensures a higher data reliability rate by 2 means. Firstly, by using TCP/IP as the underlying transport protocol and next by ensuring that all data reaches the receiver before disconnecting from the network.

IV. Experiments

This current protocol is being used in the MobiCare Project[10] that is being exhibited in FusionWorld, Singapore [11] as well as being in clinical trials in a local hospital. It has promised the capabilities as written above to the MobiCare Project.

For our experiment, we are using ECG sensors from Alive Technologies [1]. The ECG sensor samples at 300Hz for ECG and 75Hz for accelerometer readings. Based on our MobiCare Technology [10], the instant heart rate is calculated based on a moving average of 5 samples, therefore except for the first 4 initial sample values, the instant heart rate would be also be at 300Hz. However, to demonstrate the time synchronicity property of our protocol in this experiment, we have set constraints on the heart rate and accelerometer data. The data is transmitted through a minimal of GPRS mobile wireless internet. Fig 12 shows the current user-interface the clinicians used to receive the medical measurements from the mobile phone.

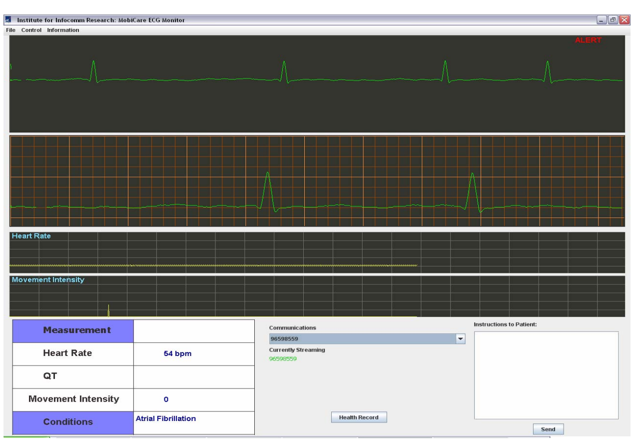

Fig 12. Screen-shot of MobiCare internet user interface

Once transmission starts, it takes only 2-3 seconds for the packets to be decoded and displayed on the user interface. The data is stored at 2 separate locations. It is stored on the server and also on the desktop of the local terminal running the user-interface. It has been demonstrated that the data transmitted is close to real time given the network latency. We have tried with multiple devices from multiple mobile phones. We are able to switch to view data from different patients instantaneously and continuously.

V. Conclusion

Primarily, current regulatory information protocols did not account for how it will operate in a mobile ubiquitous environment that has multiple real-time data transmissions. They were formed on the basis of documents exchange as opposed to raw information exchange. This has led to many companies to invent their unique protocol for their own purposes. With this proliferation of the creations of individualistic information exchange protocols, diversification of information exchange is present; minimizing the interoperability of the information.

The next concern is that current protocols are developed with the notion of document exchange as oppose to raw real-time clinical data exchange. Aspect like time synchronicity between 2 mutually exclusive data like blood pressure and heart rate would be lost if conventional information exchange protocols are used. And protocols with XML as the underlying structure will incur more overheads.

Tele-medical informatics is becoming a critical field for many countries that may not have immediate access to a medical facility. Hence, we have created a special medical information exchange protocol to cater for tele-medical monitoring to be a more viable option for the future. We have demonstrated that it works in our experiment and is currently in clinical trials in one of our local hospital. For our future research, we intend to add and test out more types of sensor in order to push the scalability of the protocol and to further improve on the usability of this protocol.

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