A Telecare System on Smart Watches that Communicate with Wireless Bio Sensors

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Abstract: In this paper, we propose a prototype of telecare system by using wristwatch-type devices, so called smart watches. In the prototype system, the smart watch receives physiological data of a user, such as heart beats and body movements, by communicating with a wireless bio-sensor worn by the user. The smart watch sends the physiological data to the other users' smart watches connected to the Internet. The sensed data are shared among family members in a peer-to-peer manner so as to remotely monitor the physical health status of the other members. We have designed a user interface which visually shows the remote user's current body posture and enables the others to tactilely feel his/her heart beats. We describe the overview of this prototype system and its user interface implemented with the smart watches. We show experimental results of communication performances of the system.

1 INTRODUCTION

Recently, wristwatch-type information devices, so called "smart watches", have drawn attention of industrial and research communities. In general, the wristwatch-type information device is regarded as a peripheral device of smartphone because it is a small sensing device attached with the user's wrist to sense her/his activity and shows alerts of the connected smartphone, such as when a mail is received. However, some of them can be used as stand alone devices which do not need to work with smartphones because they have wireless communication modules, such as Wi-Fi and LTE (4G), to independently communicate with other devices on the Internet.

In addition, as a user interface device, wristwatch-type devices have distinguished features from the smartphones. For example, a feature is intimacy of the devices: they are attached with the users wrists and stay close with the users at all times; they can directly provide tactile information for the users by using their vibration. By utilizing this feature, we can create a new service that directly and successively provides the telecare information with care givers. An example of such intimate service is "Mediated social touch," (Haans and IJsselsteijn, 2006). It is an important issue in teleacare researches how we can mediate social touch and tactile information between family members.

In this paper, we describe a prototype of peer-to-peer telecare system by using wristwatch-type information devices instead of smartphones. The system is implemented with small wireless bio-sensors and wristwatch-type devices. Physiological information of a service user, such as electrocardiogram and body movements, are sensed by the bio-sensor and shared with the others' devices in a peer-to-peer manner. Utilizing the above features of wristwatch-type device, we have developed a user interface which visually shows the remote user's current body movements and enables the others to tactilely feel his/her heart beats. The user interface has been designed to realize intuitive communication in family members. First, we describe overview of the system and its user interface. Then experimental results to investigate its communication performances are shown.

2 BACKGROUND

Mobile sensor devices have been used in telecare services to remotely monitor statuses of older persons who live alone (Lin, 2012)(Triantafyllidis et al., 2015)(Sashima et al., 2008). The services provide their health and activity statuses, which are obtained by the wearable devices, for their trustworthy persons

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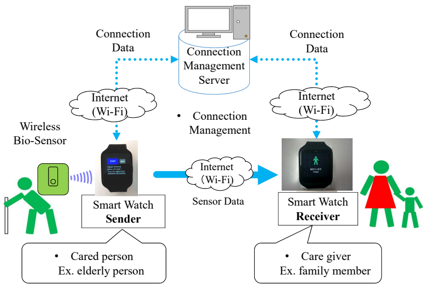

Figure 1: Overview of telecare service for elderly person.

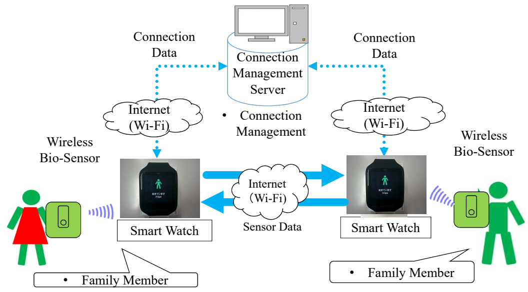

Figure 2: Overview of P2P telecare service for family members.

who take care about them, such as caregivers, family members, doctors, by using smart phones.

So far, in order to implement such telecare services, most of them have been built based on *server-client communication model*; all of sensing data of the older person are sent to a central data server and the server manages and provides the data of the users. However, the approach has a drawback to start up and maintain a practical service in reality. It is about management costs of the physiological sensing data in a central data server; the management costs rise as increasing personal health data in the server because it requires careful handling.

In order to prevent the management issue arising from the server-client model, we have proposed *peer-to-peer communication model (P2P communication model)* for telecare services (Sashima and Kurumatani, 2016). The P2P communication model assumes that the smartphones of the users directly communicate with each other in a peer-to-peer manner. The sensing data are directly sent to a smartphone of a caregiver not going through a central data server so that the management cost is less.

In this paper we apply the P2P communication model to a telecare system on wristwatch-type devices. We have implemented a prototype of telecare system based on the P2P communication model and evaluated the validity of the system. In addition, we propose a user interface that fits for wristwatch-type devices.

3 TELECARE SERVICE MODELS

We propose two service models using the peer-to-peer telecare system implemented on wristwatch-type devices;one is for elderly person is shown in the figure 1; the other is for family members is shown in the figure 2.

3.1 Telecare Service for Elderly Person

In “telecare service for elderly person” model, we assume that the service consists of a wireless bio-sensor, a connection management server, a wristwatch-type device of sensed user and a wristwatch-type device of remote user. The service user, who wears a wristwatch-type device and a wireless bio-sensor, is an elderly person living in the nursing care facilities which has Wi-FI access points. The other remote users are care givers (e.g., family member, medical staffs). The bio-sensor senses the user’s physiological data, such as electrocardiograph data, and wirelessly sends the data to the his or her wristwatch-type device. The data which represents the user’s physical status are sent to the other remote wristwatch-type devices connected to the Internet. The network address of the remote devices, which is used for establishing a communication channel among devices, are sent by the connection management server. Hence, it is possible to share the latest physical status of the user by using the wristwatch-type device.

3.2 P2P Telecare Service for Family Members

In “P2P telecare service for family members” model, we assume that the service consists of a connection management server, two wireless bio-sensors, and two wristwatch-type devices. Each service user has a wristwatch-type device and a bio-sensor. This model is a symmetrical telecare service model for family members; each member can be take care of other members. The difference between “telecare service for elderly person” model and this model is that the data flows in both directions between the wristwatch-type devices.

4 IMPLEMENTATION

4.1 System Components

The system consists of the following components.

4.1.1 Wireless Bio-sensor Device

A wireless bio-sensor device is shown at the left side in Figure 3. The sensor device is attached to a user's chest by sticking electrodes with a peel-off sticker. The device consists of 5 kinds of sensors (electrocardiograph, 3-axis accelerometer, barometer, thermometer, hygrometer), a lithium ion battery, and a Bluetooth[1] module which communicates with a smart watch. In the prototype, the device continuously senses electrocardiographic data and 3-axes acceleration data of the user and wirelessly sends the data to the smart watch.

4.1.2 Wristwatch-type Information Device (Smart Watch)

We have implemented the system on the Android Wear smart watches[2]. The wristwatch-type information device is shown at the right side in Figure 3. It commutates with a connection management server to know the network address of remote user's device. By knowing the latest address of the device, it relays the physiological data obtained by the bio-sensor to the remote user's device in a peer-to-peer manner. Using a graphical user interface of the system, the other user can know the his or her physical status visually. We can configure the system settings e.g., specifying a opponent service user, by the user interface. The system can inform the user's status by control the inner vibrator. In this research, we use the vibrator to provide remote user's heart beats.

4.1.3 Connection Management Server

A connection management server stores the network address (IP address and port number) of each user's smart watch, and dynamically updates them when the smart watch connects from a different network environment.

The network address of wristwatch-type information device is dynamically changed according to its network environments. To enable two devices communicate with each other, the network address of the peer is required.

[1]https://www.bluetooth.com/

[2]https://www.android.com/wear/

Figure 3: Wireless bio-sensor (left) and wristwatch-type information device (right).

To solve this issue, we have introduced a connection management server in the system. A connection management server stores the network address of each user's watch devices, and updates them when the device starts to connect to the server. It also tells the updated address to other devices. By knowing the latest address, the devices can communicate each other even if the addresses are dynamically changed.

Notice that the server does not handle sensing data but just initiates the communication of users.

4.2 Communication

The current wristwatch-type devices have Wi-Fi communication facilities and directly communicate with the other devices using Internet Protocols, such as UDP. We use the communication facilities to implement the telecare system that can send and receive UDP packets between the devices.

4.2.1 Communication Protocol

We adopt a protocol which has been proposed for fast communications of mobile devices (Sashima and Kurumatani, 2016). Figure 4 shows an outline of the protocol. It is a right-weight protocol, which does not have a mechanism to handle lost packets, so as to be suitable for the limited computational resources of wristwatch-type devices. In addition, as it does not wait to receive acknowledge packets, it can immediately send the packet that represents the latest user status. However, as losing packets is a weak point of this protocol, we describe experimental results of communication performances of the system in a later section.

To establish a communication channel between a wristwatch-type information device in a private network and the device in the outside of the network, we apply the NAT traversal technique (Ford et al., 2005) that enable peer to peer communications over a NAT router.

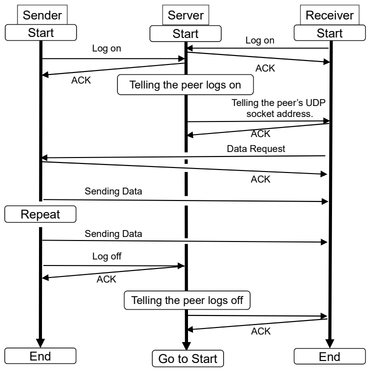

Figure 4: Overview of the communication protocol (Sashima and Kurumatani, 2016).

4.3 Data Representation

To share the sensing data between the devices in the service, the data has two data representations for the service models: a) "raw data representation" which includes raw sensing data and b) "abstract data representation" which includes the data analyzed at a wristwatch device connecting to wireless bio-sensor.

4.3.1 Raw Data Representation

This representation includes raw data obtained by the bio-sensor for the application that requires to know detailed data of the sensed user. We assume that typical usage of this representation is for medical applications, such as remote monitoring of electrocardiograph. Thus the communication is one way from a sensed user to a care giver, such as medical staff. This raw representation data is synchronously sent at a constant sensing interval. For example, if the sampling period of the sensor is 5 msec, the data is sent at each 5 msec interval.

4.3.2 Abstract Data Representation

two way communication assumed in "P2P telecare service for family members" requires more computational power for handling traffics. We have developed the abstract representation to reduce the traffics in the two way communication. The representation includes an abstract data summarized by a data sequence of raw sensing data: a "posture" data of the abstract representation is derived by analyzing a sequence of 3-axes acceleration data; and a "heart beat" data is derived by analyzing a sequence of electrocardiographic data. In addition, the abstract representation data is asynchronously sent when the system detects a change of the status. For example, the data is sent as soon as possible when the posture of the user is changed. Hence, using this representation, the amount of traffic data becomes 10–100 times smaller than using the raw data representation in our prototype system.

4.4 User Interface

The wristwatch type device is tactilely attached with the user's wrist and stay close with the user at all times. To utilize the features of the device, we have designed a user interface which directly and successively provide telecare service to the user. The user interface visually shows the users' current body movements and enables the user to tactilely feel other user's heart beats.

4.4.1 Graphical User Interface for Showing User's Status

Because the wristwatch-type device has a small display, we have designed a simple graphical user interface showing the status of the remote user. Figure 5 shows display images of the user interface. In the figure, each image shows a physical status of the remote user. Currently, the system classifies the following 6 statuses: standing, moving, laying-up, laying-down, walking, unclassified. The system automatically classifies the status based on the 3-axis acceleration data obtained by a wireless bio-sensor. The sampling rate of the data is 100 Hz. For the classification, we have used a rule-based algorithm using predefined threshold values.

To share the classification with the raw data representations, the devices share the raw acceleration data and do the classification based on the data independently. Because the classification process is done by each device, the analysis results can be slightly different between the devices.

To share the classification with the abstract data representations, the devices connected to the bio-sensor analyses the raw acceleration data and send the abstract posture data to other devices. Because the classification process is done by a device, the same analysis results are shared by the devices.

4.4.2 Tactile User Interface for Feeling Heart Beats

Based on electrocardiographic data obtained by the wireless bio-sensor, the system automatically detects the pase of heart beats of sensed user. To detect the pase of heart beats, the system monitors peak locations of the R-wave by calculating differentiation values of the electrocardiographic data, and detect sharply changing points as the peaks of the R-wave.

Figure 5: Graphical user interface of the prototype system. Each image shows a physical status of a remote user: standing (left), moving (center), laying up (right). HR field shows the pase of heart beats of the user.

The sampling rate of the data is 200 Hz. It calculates “beats per minute (BPM),” which stands for the pase of heart beats. The BPM is based on the latest R-R period, and shown at the heart rate (HR) field in the graphical user interface (see Figure 5).

To share the pase of heart beats with the abstract data representations, the device is connected to a wireless bio-sensor. It detects an R-peak from the electrocardiographic data and repeatedly sends a packet to remote user’s wristwatch device. We call the packet corresponding to the detected R-peaks R-peak packet. When the remote user’s device receives the R-peak packet from sensed user’s device, it immediately vibrates for a short time (30 msec). Hence, it vibrates in synchronism with the heart beat of sensed user so as to others can tactilely feel his/her heart beat by the vibrations. Strictly speaking, as there are delay times to receive the R-peak packets and the times fluctuate with network conditions, others can tactilely feel ”his/her heart beat like pattern” by the vibrations.

To share the pase of heart beats with the raw data representations, the devices sends the raw electrocardiographic data to the other users. The others calculate the BPM based on the raw data independently.

5 EVALUATIONS

We have experimentally evaluated communication performances by measuring the packet loss and end-to-end delays of the prototype system.

The experimental network environments are a Wi-Fi network (LAN) in our laboratory. We have measured the communication performance of two devices which connect to the same Wi-Fi access point that might be used by the other users. To prevent the effects of the sleep mode of the devices, we have applied power to USB ports of them.

We have evaluated communication performance in the following two conditions assuming the different service models: *one-way communication* used for “telecare service for elderly person,” and *two-way communication* used for “P2P telecare service for family members.” For the above two conditions, we have compared the performance between the abstract data representation and raw data representation. We have analyzed the performance based on the data recorded by each device in each condition. We have used the data recorded within ten minutes from the starting time of the communication.

5.1 Packet Losses

Experimental results about packet losses between the wristwatch-type devices are shown in Table 1. Total samples means a total number of the data sent by the devices. The “condition” column of Table 1 shows combinations of communication styles and data representations. For example “Two Way/Raw” stands for two way communication with raw data representation. Using the abstract representation, the total numbers of data became small in this experiment because the data is sent asynchronously when the user changed his or her posture.

While many packets were lost by using the raw representation especially in the two way communication, few packets were lost by using the abstract representation. Because the wristwatch-type device has limited computational resources, the abstract representation with asynchronous communication is more suitable for the prototype than the raw representation.

5.2 End-to-end Delay

We have measured delay times of the communication in the conditions. The results are shown in Figure 6. Before the experiments clocks of the devices are synchronized based on a clock of the connection server. The average delay time of “Two Way/Raw” condition is omitted in the graph because it took for a long time

Table 1: Experimental results of packet losses.

condition	total samples	lost samples	loss rate (%)
One Way/Raw	180000	677	0.4
One Way/Abstract	870	0	0
Two Way/Raw	360000	149845	41.6
Two Way/Abstract	3267	4	0.1

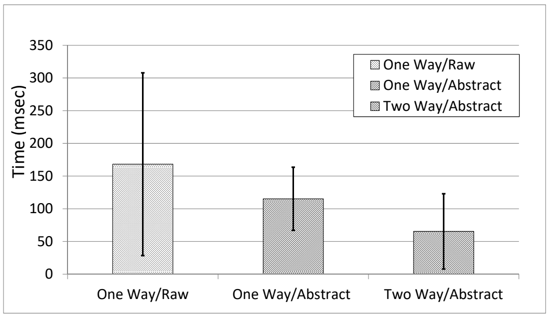

Figure 6: End-to-end delay times (msec).

(over 30sec). Average delay times of the other conditions are under 200 msec. Although more careful investigations are required in various network conditions, we believe that the result shows the feasibility of the telecare services by using wristwatch-type devices.

6 CONCLUSIONS

We have described a prototype of peer-to-peer telecare system by using wristwatch-type information devices not using smartphones. Physiological information of service user, such as electrocardiogram and body movements, sensed by the wireless bio-sensor are shared among the service users' wristwatch-type information devices in a peer-to-peer manner. To realize intuitive communication between family members, we have developed a user interface which visually shows the sensed user's current body movement and enables the others to tactilely feel his or her heart beats. We believe that the system opens up a new design space in which all users in a social group can take care of each others at the same time.

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