HealthCom 2013 - 15th IEEE Intl. Conf. e-Health Networking, Applications and Services. Lisbon, Portugal. 09-12 Oct 2013.

# Alerts for Remote Health Monitoring Using Online Social Media Platforms

Chonlatee Khorakhun
University of St Andrews, UK
ck46@cs.st-andrews.ac.uk

Saleem N. Bhatti
University of St Andrews, UK
saleem@cs.st-andrews.ac.uk

***Abstract*—Alerts are an essential part of future remote health monitoring. We assess the feasibility of leveraging online social media for such capability to enable the delivery of healthcare outside clinical sites. We have implemented medical alerts triggered by bio-data and notifications of management-related actions in relation to the operation of an example heart-monitoring application. We have examined the suitability of online social media platforms using Facebook. A Facebook application was developed to deliver configurable alerts to four different actor viewpoints in a *carer network*; the patient; the doctor in charge; the professional carer; and a family member of the patient. The suitability of the application was analysed as well as an initial examination of the reliability of alert delivery. We conclude that online social media platforms could offer suitable platforms for alerts in remote health monitoring.**

## I. Introduction

*Remote health monitoring* will play an important role for future eHealth scenarios. Our preliminary investigations have shown that remote health monitoring using a smartphone to collect health data [1] and using an *online social media platform (OSMP)* to access the collected health data are feasible [2]. In this paper, we focus on *alerts* for use in remote health monitoring. Using a *remote monitoring application (RMA)*, healthcare processes conducted at clinical sites can be moved outside clinical environments. This has the potential to: reduce healthcare costs by reducing time spent by healthcare workers performing routine monitoring on patients at a clinical site; improve quality of healthcare services through more pervasive monitoring; and also improve a patient's quality of life by allowing them to spend less time at a clinical site. An example scenario is care of the world's ageing population: the UN has growing concerns about the rapid increase in the proportion of the population over 60 years of age [3].

### A. Carer network

We have proposed the use of a *carer network* [2] as a natural social network within a healthcare environment. Figure 1 shows our *carer network*, based on a healthcare regime that is common in the UK. The actors in the carer network could communicate via an OSMP that implements a *remote monitoring application (RMA)*. The four actors in our scenario are: the *doctor* in charge of the management of the care regime; the *professional carer* implementing the clinical care; a *family* member or friend who is concerned about the patient (e.g. a neighbour for an elderly patient); and the patient. By exploiting existing infrastructure (OSMP software and network connectivity), fast development can be enabled and adapted quickly to suit requirements. OSMPs provide basic security and privacy mechanisms for access control of collected health data, but a real deployment would need to improve on what is currently available, as discussed in our previous work [2].

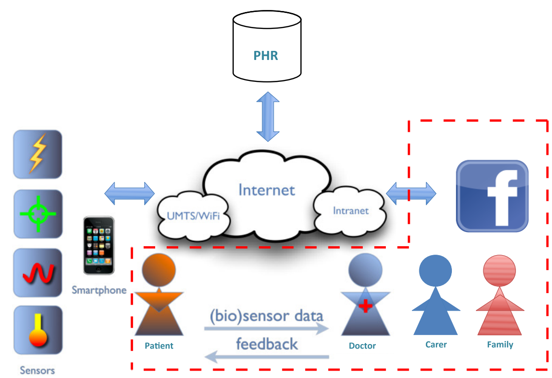



Fig. 1: A remote monitoring application (RMA) using an online social media platform (OSMP) to form a *carer network*. We consider heart monitoring of an elderly patient, and focus on *alerts* implemented using the notification services of the OSMP. Under configuration control, alerts are sent to appropriate actors. Our example application uses Facebook. The dashed (red) outline shows the scope of our study.

### B. Scenario

This work is part of an ongoing study to assess use of OSMPs in the context of remote health monitoring. Coupled with appropriate sensing and communication systems, alerts could be used for a variety of purposes within the healthcare regime, e.g.:

- Notifying the carer network members about changes in a patient's condition.
- Flagging changes in operation of the RMA, e.g. the RMA is turned on or off.
- Sending periodic reminders to the patient to undertake a certain action, e.g. take medication.
- Allowing healthcare workers to send asynchronous requests to a patient as part of the overall healthcare regime.

In this paper, we consider the first of these only, and will present others in future work. We take the position that such alert-based systems will, initially, *not* be used for critical care, e.g. a patient with a severe heart-condition. Instead, we consider alert systems as part of care regimes dealing with more routine monitoring of less critical conditions; or for ambulatory monitoring and data collection in diagnosis; or for gauging the effectiveness of ongoing treatment.

Figure 1 shows our example scenario in which an elderly patient is undergoing heart monitoring. We also do not consider the sensors involved, but much suitable technology is available for for use in such systems, e.g. wireless smart watches [4], for heart rate monitoring. The detection of heart rhythm disorders and symptoms like *arrhythimias* may also be possible using appropriately instrumented pacemakers [5], for example. Currently, such devices lack an 'application portal' to provide access to the monitored data, and we propose an alert system as being a part of such a portal.

After describing related work in Section II, we analyse our requirements in Section III. We describe in Section IV our application development, and present analyses of its suitability in Section V, finishing with a short conclusion in Section VI.

## II. Related Work

SMS has been used to send notifications or alert messages in telemedical applications. In such systems, a local PC receives monitored health data via a short range communication, e.g. RF or bluetooth, and sends SMS. Previous work [6] [7] shows example systems in which SMS messages are sent to concerned medical experts and/or to relatives by a GSM modem attached to a local PC when monitored vital signs exceed a threshold. SMS has also been used in telemonitoring for transmitting monitored health data which does not need high bandwidth. Other work [8] [9] has proposed the use of the SMS platform for health monitoring with fully automatic transmissions via GSM.

In ubiquitous health monitoring, mobile health monitoring uses a smartphone as an Internet gateway to send collected health data to a remote server. In emergency situations, a server can possibly send an alarm or alert message via the Internet, SMS or email to handheld devices. However, in such systems, e.g. [10] [11] [12], SMS is still mainly proposed as a means for sending alerts. Similar to our work, [13] proposes heart disease monitoring and alerting systems using a smartphone.

While SMS and the use of a smartphone for sending alerts have been considered previously, there has been no work examining the use of OSMPs, and the use of an Internet-protocol-based network has been limited to the use of email. Our previous work [2] establishes the use of OSMP as a richer platform (in terms of functionality and data types), allowing communication within the carer network. However, we have not previously considered in detail the use of the alert systems.

Clinical sites are increasingly able to use a variety of communication coverage (e.g. 2G/3G/4G mobile, WiFi/WLAN), and industry has mature healthcare communication systems and products, e.g. Cisco[1], IBM[2] Juniper[3]. One major benefit of using OSMPs is that existing communication and system infrastructure can be leveraged, reducing costs and improving development capability. Many OSMPs, such as Facebook and Twitter, offer APIs to connect with SMS as well as being accessible via Internet connectivity. However, an opensource OSMP, such as Diaspora[4], can provide maximum flexibility for connectivity, as well as allowing enhanced application capability and customised security and privacy controls.

## III. Requirements

As we have shown in [2], information sent to and received from an RMA could be related to health bio-data (user plane), control (plane) data for the configuration of the application, or management (plane) data related to the overall operation of the application (systems-related), or the health-regime policy (user- related). Hence, we chose to specify three main types of alerts, based on Figure 1:

- *bio-data alert:* This alert type is triggered from the bio-data, e.g. by the use of threshold triggers. Health alerts are sent to appropriate actors in a carer network.
- *system alerts:* This type of alert is triggered by a change in the configuration of the RMA. For example, when a patient switches on/off the monitoring, alerts will be sent to notify a healthcare professional in the carer network. Also, any configuration signal sent by a carer, e.g. adjusting of monitoring frequency should trigger an alert sent to the doctor responsible for overall care.
- *messaging alerts:* This type of alert is for user-level messages, either sent by manual intervention (e.g. a message from a doctor to enquire about a patients care) or automatically generated (e.g. a reminder for medication).

We consider these to be notification *primitives*, and further, higher-level alert-types could be realised based on these, as appropriate for a particular application. In this paper, we examine the first of these. Alerts will be sent according to the values of monitored bio-data. We have chosen to emulate a heart-monitoring application with the following states:

- *Normal:* The monitored bio-data are in normal ranges. No need for any action.
- *Warning:* The monitored bio-data starts to deviate from normal values. Patients need to be notified to be aware of the situation. There is no need yet for doctors to take action, but, depending on the healthcare regime, a professional carer or family member may be notified.
- *Critical:* The patient is in a situation where some intervention is required by a medical professional. All actors will be alerted of this situation with urgency.

The state diagram is shown in Figure 2, while Table I shows the alerts that are generated and which actors receive the alerts. Of course, this table could be configured as required for a particular patient or particular healthcare regime. For simplicity, we have so far considered a single actor for each part of the carer network. However, it is clear that the various

[1]http://www.cisco.com/web/strategy/healthcare/
[2]http://www.ibm.com/smarterplanet/uk/en/healthcare_solutions/ideas/
[3]http://www.juniper.net/uk/en/solutions/enterprise/healthcare/
[4]http://diasporaproject.org

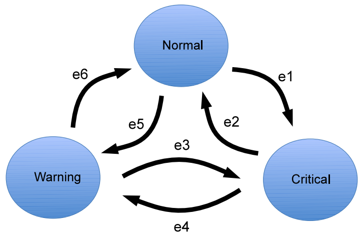



Fig. 2: A state diagram showing all possible changes in health status and events (see Table I) triggered by each change for our emulated heart-monitoring application.

TABLE I: Events signalling a state change (see Figure 2).

| | e1 | e2 | e3 | e4 | e5 | e6 |
|---|---|---|---|---|---|---|
| Patient | yes, high | yes | yes, high | yes | yes | yes |
| Family | yes, high | yes | yes, high | yes | yes | yes |
| Carer | yes, high | yes | yes, high | yes | no | no |
| Doctor | yes, high | yes | yes, high | yes | no | no |

yes = alert sent    no = alert not sent
high = high level of reliability / urgency

actors we have chosen could in fact be *groups*, and the alerts are delivered to everyone within the group identified.

The triggering of alerts needs to be highly configurable, but the generation of alerts should not have to rely on manual intervention, i.e. should be automated via the OSMP. Where, 'high' urgency or reliability of delivery is needed for alerts, then the OSMP should support some sort of additional reliability mechanism accessible to the application developer, e.g. OSMPs can offer delivery of notifications via SMS as well as via the normal delivery mechanism via the Internet. However, the exact nature of the urgency/reliability mechanism would be application-specific.

## IV. Application Development

Our RMA is a proof-of-concept – we discuss in Section V how our findings might impact the design of a real-world implementation on an OSMP.

Figure 3a shows an overall view of our experiment. The emulated heart-rate bio-data is collected every 20s from our 'patient' and stored in a MySQL database. A Facebook application polls the data every 1 second and generates alerts as required, based on the discussion above (see Figure 2 and Table I). This means that alerts should be available within ≈20s of an event occurring at the patient, and of course this could be changed as required. Given the nature of the monitoring – non-critical – sub- second alerts are not required. (Polling-based systems have inherent scalability issues, but our intention here is to understand if timely delivery of alerts is feasible.) We record a timestamp when the alert was generated at the 'patient', then check the Facebook timestamp when the notification was visible to an actor.

### A. Use of Facebook

The Facebook application accesses the MySQL server and displays the monitored data in a Facebook canvas application. Each actor would see a different viewpoint, for user-, control- and management-planes, based on requirements [2]. When the monitored bio-data reaches predefined thresholds or there is a configuration change in the application, alerts in the form of Facebook notifications will be generated.

We have implemented bio-data alerts and system alerts. For the bio-data, the thresholds would be tuned to a specific patient as required. For our proof-of-concept, we have used a simple threshold model based on a document from *Heart Research Australia* [14] (bpm = beats per minute):

- *Normal:* 60-80 bpm.
- *Warning:* 50-60 bpm or 80-100 bpm.
- *Critical:* less than 50 bpm or greater than 100 bpm.

### B. Alert delivery latency

A smartphone with browser access to Facebook was tested on 3G and WLAN connectivity each for a 2-hour period. The emulated patient was configured to generate 3 notifications per minute. The distribution of latency of alerts is shown in Figure 4 with some statistics in Tabel II. Overall, our simple experiment shows that the alert delivery latency using Facebook is low.

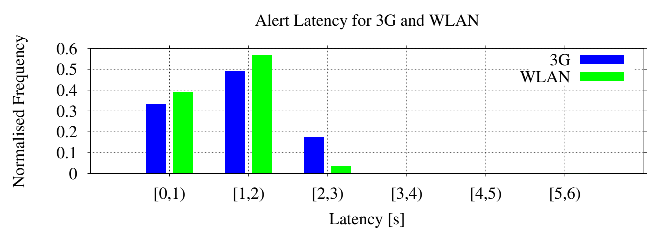



Fig. 4: Alert latency: Facebook to smartphone, distribution.

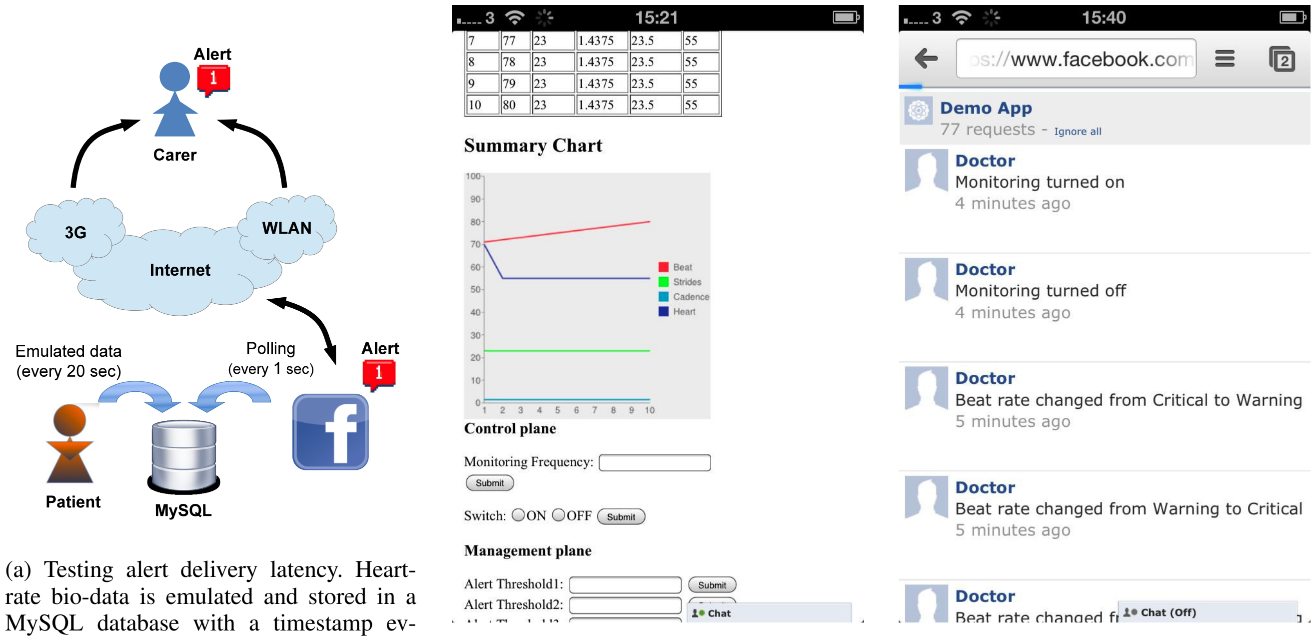
TABLE II: Alert latency: Facebook to smartphone, statistics.

| | mean | max | median | range | 95%-tile |
|---|---|---|---|---|---|
| 3G | 0.8 | [2,3) | 1.0 | 2 | 2.0 |
| WLAN | 0.6 | [5,6) | 1.0 | 5 | 1.0 |

latency values all in seconds

Alerts are sent to the predefined group of people according to Table I. We are aware that there are other factors that could affect the heart rate, e.g. activities, temperature and body size. Therefore, additional bio-data and a more sophisticated model would be needed to detect the abnormality correctly, in reality.

Using an OSMP for remote monitoring would allow a range of user terminals for the actors, e.g. desktop, tablet, smartphone. We choose to use a smartphone, as alerts are asynchronous, and so actors, such as family members and carers, may chose to monitor such alerts while engaged in other activities which mean that the use of a desktop or tablet is not possible. Figure 3b shows an application dashboard for doctor viewpoints, allowing views of various bio-data as a table and graphs. It is possible via the dashboard to change RMA configuration, e.g. switch on/off or change monitoring frequency. Alerts are implemented as Facebook notifications, e.g. Figure 3c. Facebook groups are used for actors and individual users are assigned to the appropriate group.




(a) Testing alert delivery latency. Heart-rate bio-data is emulated and stored in a MySQL database with a timestamp every 20 seconds. Our Facebook application polls the database every second, issuing an alert when new bio-data is seen.

(b) The Facebook application: doctor viewpoint. Dashboard access to bio-data and application control.

(c) Alerts delivered as Facebook notification messages: doctor viewpoint. Both bio-data and system alerts are shown.

Fig. 3: The Facebook application: a proof-of-concept with emulated heart-monitoring.

## V. Discussion and Analyses

As discussed in Section II, other researchers have used SMS for messages and alert delivery. However, there are benefits of using OSMP over SMS. For example, where remote monitoring is in the home or office environment, WLAN connectivity may offer better reception than SMS indoors. Additionally, the OSMP enables appropriate relationships and communication channels between the relevant actors in the carer network. An OSMP allows leveraging of existing infrastructure, reduced costs, improved developer access to APIs, and gives the potential for rapid application development.

### A. Twitter

Twitter might seem the obvious choice for alerts. Twitter uses messages of 140 characters to fit the SMS size limit of 160 characters. There are three ways to get access to Twitter: web portal, mobile application and the SMS API. There are two ways to generate messages in Twitter:

- *Tweet:* This is delivered based on a ‘follows’ relationship, in which a user subscribes to delivery of messages from another user. Unlike ‘friending’ in other social networks, this is not a two-way relationship. Also, privacy is very coarse grained, and permissions based on groups are not possible: public tweets are visible to everyone, whereas protected tweets will be seen only by followers.
- *Direct message:* Single, personal, user-to-user messages, only to a follower if privacy is used.

Such a coarse level of control is not suitable for our RMA, as we can see from Section III. We need a finer level of granularity for controlling the way alerts are delivered. Twitter would not support well the relationships and communication channels for a carer network. Using a single, central account for all actors in a carer network to follow tweets and receive direct messages might be practical in some circumstances. Although it is possible to automate direct messages to followers, the number of direct messages is limited by the platform to 250 direct messages per day. However, Twitter may offer an alternative delivery mechanism in order to support more urgent/reliable message delivery, notwithstanding that other mechanisms may also be available.

### B. Facebook

Unlike Twitter, Facebook provides mutual relationships and richer social channel constructs, with a range of possibilities for communication between users, as well as privacy settings to control who can see any messages. Facebook provides functionality to connect users as a *group* or a *list*. Based on an open graph mechanism, a relationship between users is enabled, e.g. patients can have lists of people who are their doctors. Also, carers and family members can be grouped by Facebook for communication within a carer network. There are three relevant methods for messages in Facebook:

- *Post to a user’s timeline or to friend’s news feed:* By using a feed dialogue, a user’s ‘status update’ is made visible to friends or made public. A graph API could enable an automatic post. However, if users create an incorrect privacy setting, the information could be either exposed to the whole network or may not go to the correct people.
- *Send a message:* A message is sent directly from a user to others. This way, information can always be kept private. However, it is not possible to automate the message sending – user interaction is required.

- *Notifications:* A notification enables users to send a short custom message. Only receivers can see the notification pop up when they log in. So, the information is kept private. In addition, an automated process for sending a notification is possible. However, some user interactions are still required at the beginning of the process to grant permissions. This method is best suited for sending alerts for health monitoring application.

Facebook offers the following features which can be utilised for the RMA alert system within the carer network:

- *Relationships.* A Facebook *group* or *list* can allow the formation of the carer network. Facebook also supports communities and friends across the groups and lists.
- *Communication channels.* Facebook supports better access control compared to Twitter, e.g. *post to news feed* can be sent to a specific users individual timeline. Considering private and direct communication, a *direct message* is possible in Facebook as well as notifications.
- *Automation.* Automatic processes for generating alerts are possible in Facebook, with no constraints, as far as our RMA is concerned. Facebook has no limitation on the number of messages that can be sent. Automation of notification generation is possible in Facebook, but user interaction is still required at the beginning of the process.

Facebook offers a deprecated API for SMS services.

### C. Security and privacy using OSMP for RMA alerts

Our examination of Facebook has informed us: (a) that such a platform offers a suitable model for building RMA alerts; and (b) what limitations might exist which would need to be addressed in a real OSMP if it were used for eHealth RMAs and alerts. A more detailed discussion of the privacy, security and access control aspects can be found in [2]: such mechanisms must remain under the control of the carer network, but in the Facebook platform, the policies are controlled by Facebook and could change arbitrarily. However, use of an opensource OSMP, such as Diaspora, would enable RMA functionality, including alerts, as well as customised privacy and security. A real eHelath RMA system built from such an OSMP could be administered by a health service provider, further improving the security and privacy aspects for collection of the bio-data.

## VI. Conclusion

We have examined the provision of alerts for a remote health monitoring (RMA) application by leveraging an online social media platform (OSMP). Using Facebook as our example platform, we find there are many facilities and features that such an OSMP can offer for RMA alerts. The use of an OSMP allows us to implement communication between actors in a *carer network* which includes the patient and medical professionals. The OSMP also allows alerts to be delivered as Facebook notifications. We have found that the latency of delivery of such alerts is perfectly acceptable over WLAN and 3G, with alerts typically delivered in a few seconds. Our proof-of-concept implementation of an alert mechanism shows the feasibility of using OSMPs for alerts.

However, there are some challenges we have founded with the use of the Facebook platform, with respect to providing appropriate security, privacy and access control. These can be used to inform the implementation of a system for future real RMA systems based on an opensource OSMP, for example.

For a real deployment, more development would be needed as well as enhanced reliability, security and privacy mechanisms. This might be enabled through the use of an opensource OSMP, e.g. Diaspora. By examining the features and properties of existing platforms, like Facebook and Twitter, it is possible to refine the design of an OSMP, so it forms a suitable platform for future eHealth RMAs.

## References


[1] D. Rehunathan, S. Bhatti, O. Chandran, and P. Hui, "vNurse: Using virtualisation on mobile phones for remote health monitoring," in *Proc. 13th IEEE Intl. Conf. on e-Health Networking Applications and Services (HealthCom2011)*, Jun 2011, pp. 82–85.

[2] C. Khorakhun and S. N. Bhatti, "Remote Health Monitoring Using Online Social Media Systems," in *Proc. 6th IFIP/IEEE Wireless and Mobile Networking Conference (WMNC2013)*, Apr 2013, pre-print for review: http://goo.gl/nOZay.

[3] M. Greene, S. Joshi, and O. Robles, *State of World Population 2012*. UNFPA - United Nations Population Fund, Nov 2012, https://www.unfpa.org/public/home/publications/pid/12511.

[4] "EZ430-Chronos," http://processors.wiki.ti.com/index.php/EZ430-Chronos, (May 2013).

[5] R. P. Ricci, L. Morichelli, and M. Santini, "Home monitoring remote control of pacemaker and implantable cardioverter defibrillator patients in clinical practice: impact on medical management and health-care resource utilization," *Europace*, vol. 10, no. 2, pp. 164–170, 2008.

[6] R. K. Megalingam, V. Radhakrishnan, D. C. Jacob, D. K. M. Unnikrishnan, and A. K. Sudhakaran, "Assistive technology for elders: Wireless intelligent healthcare gadget," in *2011 IEEE Global Humanitarian Technology Conference (GHTC)*, 2011, pp. 296–300.

[7] A. Kale, S. K. Kaul, D. P. Das, and S. Raghunath, "A smart system for remote monitoring of patients and sms messaging upon critical condition," in *3rd IEEE Intl. Conf. on Wireless Communication and Sensor Networks (WCSN'07)*, 2007, pp. 141–144.

[8] C. N. Scanaill, B. Ahearne, and G. M. Lyons, "Long-term telemonitoring of mobility trends of elderly people using sms messaging," *IEEE Trans. on Inforn. Technology in Biomedicine*, vol. 10, no. 2, pp. 412–413, 2006.

[9] M. Triventi, E. Mattei, F. Censi, G. Calcagnini, S. Strano, and P. Bartolini, "A SMS-based Platform for Cardiovascular Tele-monitoring," in *World Congress on Medical Physics and Biomedical Engineering, Munich, Germany*. Springer, Sep 2009, pp. 295–298.

[10] M. J. Moron, J. R. Luque, A. Botella, E. Cuberos, E. Casilari, and A. Díaz-Estrella, "J2ME and smart phones as platform for a Bluetooth Body Area Network for Patient-telemonitoring," in *29th IEEE Annual Intl. Conf. Eng. in Medicine and Biology Society*, 2007, pp. 2791–2794.

[11] Z. Lv, F. Xia, G. Wu, L. Yao, and Z. Chen, "iCare: A Mobile Health Monitoring System for the Elderly," in *IEEE/ACM Int'l Conf. Cyber, Physical and Social Computing (CPSCom)*, Dec 2010, pp. 699–705.

[12] R.-G. Lee, C.-C. Lai, S.-S. Chiang, H.-S. Liu, C.-C. Chen, and G.-Y. Hsieh, "Design and implementation of a mobile-care system over wireless sensor network for home healthcare applications," in *28th IEEE Intl. Conf. Engineering in Medicine and Biology Society (EMBS'06)*, 2006, pp. 6004–6007.

[13] H. Watanabe, M. Kawarasaki, A. Sato, and K. Yoshida, "Development of wearable heart disease monitoring and alerting system associated with smartphone," in *14th IEEE Intl. Conf. on e-Health Networking, Applications and Services (HealthCom2012)*, Oct 2012, pp. 292–297.

[14] "Heart-Research-Australia," http://www.heartresearch.com.au/arrhythmias.html, (May 2013).