An ECG Analysis on Sensor Node for Reducing Traffic Overload in u-Healthcare with Wireless Sensor Network

Dae-Seok Lee[1], Sachin Bhardwaj[2], Esko Alasaarela[3] and Wan-Young Chung[4]

[1,2]Dept. of ubiquitous IT , Graduate School of Design & IT, Dongseo University, Busan 617-716, Korea,
[3]Dept. of Electrical and Information Eng., University of Oulu, 90570 Oulu, Finland
[4]Division of Computer Information Eng., Dongseo University, Busan 617-716, Korea
E-mail :{[1]leezzang,[2]sanusachin}@gmail.com, [3]esko.alasaarela@ee.oulu.fi, [4]wychung@dongseo.ac.kr

Abstract— **A new approach for electrocardiogram (ECG) signal monitoring and analysis for the homecare of elderly person or patients is designed and implemented. Developed platform for real-time analysis of ECG signals on sensor node can be used as an advanced diagnosis and alarming system. Sensor node does not need to transmit ECG data all time in wireless sensor network and to server. Firstly sensor node can detect abnormality in ECG then transfer abnormal ECG data in the network to server for further analysis. This system can be used to reduce data packet overload and to save power consumption in wireless sensor network. It can also increase the server performance by reducing load. The ECG features are used to detect life-threatening arrhythmias with an emphasis of analyzing QRS complex in ECG signals at a sensor node. Based on abnormal ECG activity due to R-R interval and QRS width, the sensor node can transfer ECG data to the server for extended and cautious ECG analysis and disease classification. Needed information of abnormal ECG of a patient the server can then be transferred to the doctor's personal digital assistant (PDA) for further diagnostics.**

I. INTRODUCTION

Several international projects, which use wireless sensors as a framework of a standardized body area network (BAN), are focusing on improving traffic over load between sensor nodes used. Though, none of them have possibilities of analysis function on sensor nodes. The MobiHealth System, invented by European Community(2002-2004), demonstrates the BAN [1] for u-healthcare application. Code blue[2] is a wireless infrastructure for deployment in emergency medical care. Another health monitoring system is Coach´s Companion [3], which allows the monitoring of physical activity. CardioNet employs PDA to collect data from ECG monitor and sends it over a cellular network to a service center [4]. Medtronic uses a dedicated monitor connected to the internet for sending pacemaker information to a medical professional.

In our research we are aiming to develop a robust, real-time monitoring platform mainly with ECG analysis on sensor node. An ECG analysis on sensor node can reduce the data packet overload between sensor nodes which are attached on several patients or between several sensor nodes on a patient, and save power consumption in wireless sensor network and can increase the performance at server by reducing the load on server in consequence. When sensor node detects abnormality in ECG on sensor node, the node transmit the abnormal information to server for further cautious analysis and detail disease classification through network. The information from result of abnormal ECG signal analysis at the server is sent to the doctor's or caregiver's PDA or cellular phone for further diagnostics.

An ECG is plot of the time-dependence of charging potential differences between electrodes on the body surface. Duration of ECG waves and intervals in a normal adult human heart are shown in table 1. Long term ECG analysis plays a key role in heart disease or chronic disease analysis. The long term objective, however, is to automate the ECG event classification in order to further enhance medical treatment. In order to classify the ECG signal, a reliable extraction of the characteristic ECG parameter is needed.

Table.1 Durations of waves and intervals in a normal adult human heart

Parameter	Duration (sec)
Intervals	
P-R	0.12–0.20
Q-T	0.30–0.40
Waves	
P	0.08–0.10
QRS	0.06–0.10

In our system, continuous real-time ECG analysis function with automatic event detection is implemented on sensor node. We used the variant of Pan-Tompkins real time QRS detection algorithm [5], [6] to calculate Heart Rate and variation in the R-R interval and QRS width. There are no communications between sensor nodes when the nodes don't detect any abnormality in sensor nodes, sensor nodes transfer abnormal ECG data to server for further analysis and disease classification and then can notify to doctor's PDA when the nodes detect abnormality in sensor nodes.

II. SYSTEM DESIGN

Figure 1 shows the architecture of ECG monitoring system using sensor nodes which have ECG analysis function. The system also provides a recording activity which detects and monitors events and potentially important medical symptoms by transferring data to the server for further detail analysis when the sensor node detect any abnormality in ECG signal first. The hardware allows for data to be transmitted wirelessly with analysis results from on-body sensor to the base station and then to PC/PDA.

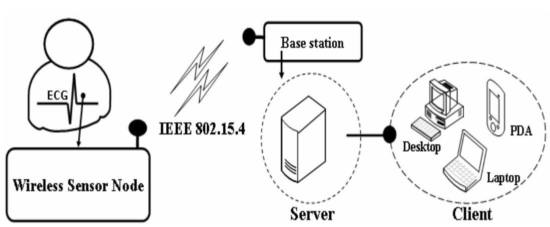

Fig.1 Architecture of ECG monitoring system with a ECG analysis sensor node.

Wireless Sensor nodes we fabricated are small hardware modules which have strong capabilities of sensing, computing and bi-directional communication with other sensor nodes or gateway of server PC. These sensor nodes can be programmed using TinyOS and they are operated by low power batteries. The sensor measures an ECG-signal with a sampling frequency of 200 Hz. We used TIP50CM (Maxfor Inc., Korea.) sensor nodes for the system accomplishment. The MIT-BIH ECG arrhythmia database[7] and real time ECG data from human body were used for system testing. The signal is digitalized with 10 bits resolution, and continuously transmitted to a receiver-module attached to PC/PDA, using a modulated RF-radio link of radio chip CC2420 (Chipcon Inc., Norway). The sensors(electrodes and interface) are attached to the patient's chest. Sensor node continuously receives measured ECG signal and wirelessly transmit sampled ECG-recordings together with analysis results using a built-in-RF-radio transmitter to the base station and then to PC/PDA through a RS-232 connector only when the analyzed ECG signal is abnormal ECG signal in a sensor node.

To detect abnormal ECG in sensor nodes, wireless sensor nodes run application software, which was developed using nesC programming language [8] which runs on TinyOS[9]. The component-based architecture and event-driven execution model of TinyOS enables fine-grained power management while minimizing the code size keeping in the view of memory constraints in sensor network.

Figure 2 shows component interface for detection of abnormal ECG on sensor node. ECGFilterM includes several filters and functions for detecting abnormal ECG. The raw ECG samples are received from UART' and processed by ECGFilterM. If abnormality in ECG is detected then data is transferred over radio using GenericComm.

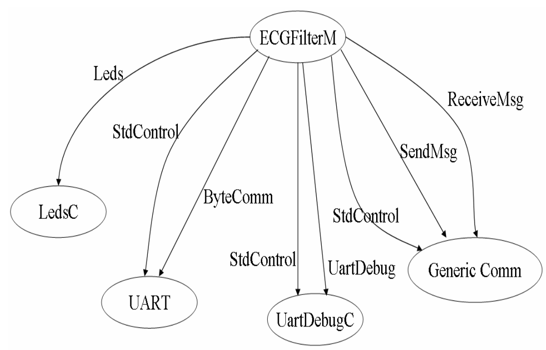

Fig.2 NesC component interfaces for ECG analysis application in a sensor node.

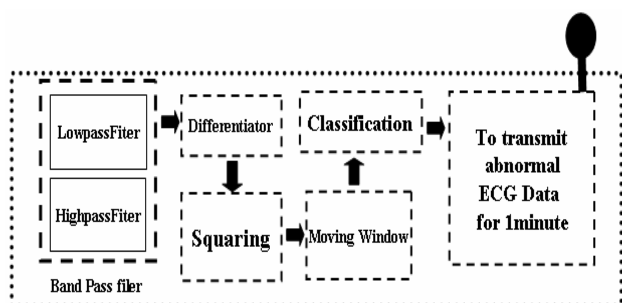

Fig.3 QRS complex detection sequence on a sensor node.

For ECG analysis on a sensor node, the variant of Pan-Tompkins algorithm is used for signal processing. This algorithm is improved according to our analysis requirements and programming which is done by nesC programming language. This algorithm proposes a real-time QRS detection based on analysis of slope, amplitude, and width of QRS complexes on sensor node. Figure 3 explains the method of QRS complex detection on a sensor node. It includes a series of filters and signal processing methods that perform low pass, high pass, derivative, squaring and integration procedures. Filtering reduces false detection caused by the various types of interference present in the ECG signal. This filtering permits the use of low thresholds and thereby increases the detection sensitivity. The algorithm adjusts the thresholds automatically and parameters periodically to adapt the changes in QRS morphology and heart rate entered into the sensor node. By using moving window integration process, we can calculate R-peaks, R-R intervals, width of QRS complex and heart rate variability. Heart rate is computed by measuring the length of the R-R interval, or a full period of the waveform. These parameters are used to detect abnormality in patient´s ECG. After detecting abnormal ECG due to QRS complex on sensor node, then transmit to the server for further ECG analysis.

Figure 4 shows QRS detection algorithm on sensor node by using filters and derivative, squaring and moving window integration methods. After detecting abnormal ECG activity then it is transmitted to the server for further analysis.

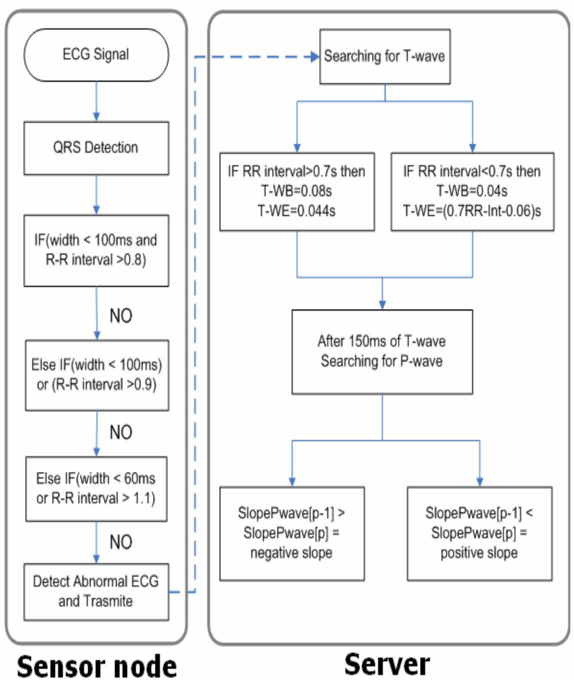

Fig.4 ECG analysis flow charts on a sensor node and in a server PC.

After detection QRS-complex, P-wave and T-wave detection algorithm searches for the T-wave first. The wave is expected to appear within a specific time window. The start and duration of the window depends on the R-R interval:

If the R-R interval>0.7s:

T-wave Window begin (T-WB) = 0.08s after QRS end.

T-wave window end (T-WE) = 0.44s.

If R-R interval<0.7s:

T-WB = 0.40s.

T-WE = (0.7R-R interval -0.06) s.

Within this window, the minimum, maximum and order of the slope of the derived function are important for detecting the T-wave. Bi-phase T-wave can be identified in the same way. The change of the slope, as well as the end of the T-wave is detected by a method which is based on thresholds. The slope must include positive and negative values and the slope magnitude needs to be at least 0.006mV/s for a T-wave to be detected. To be able to check the abnormality due to the T-wave, estimated QT-interval should be located in the T-wave window of the x-axis. This means the time period from 300 to 400ms. The P-wave is located between the end of the T-wave and the beginning of a new QRS complex. The detection rule for a P-wave is to find a positive slope followed by a negative slope. The magnitudes of both slopes have to be greater than 0.004mV/s. The algorithm searches for this combination until the beginning of a new QRS complex is detected. If SlopePwave[p-1]> SlopePwave[p] then the slope is negative and if SlopePwave[p-1]<SlopePwave[p] then the slope is positive. It will check for five consecutive slopes then can decide finally positive and negative slope. Where p is the number of slope encounter and SlopePwave is the calculated slope during P-wave detection. Initially, the value set as p=1 and SlopePwave[0]=0. Estimated P-R interval should be less than 200ms for normal ECG, which extends from the beginning of the P wave to the first deflection of the QRS complex. After calculating all parameters of ECG signal, shape and beat of ECG can then be classified. If the heart rate is greater than 100bpm then it is called sinus tachycardia disease but if the heart rate is less then 60bpm then it is called a sinus bradycardia disease. If the heart rate is between 60 and 100bpm then it is a normal sinus rhythm. Similarly, if any abnormality occurs due to QT-interval, PR-interval or heart rate, we can classify the various types of arrhythmia diseases. Based on abnormal ECG activity, the server transfers diagnostic results and alarm conditions to a doctor’s PDA.

III. EXPERIMANTAL RESULT

Our experimental set-up obtains the ECG data from the sensors placed on real human body and MIT-BIH arrhythmia database. Figure 5 shows results from measurements where data passes through the created QRS detection algorithm on a sensor node and a server. The results of each steps of detected QRS-complex on sensor node are shown in Fig. 5(a) when MIT-BIH arrhythmia database was used as ECG signal to the sensor node. Similarly the step results of detected QRS-complex on server are shown in Fig. 5(b) when ECG data received from human body was supplied to the sensor directly.

When an abnormal ECG data is detected at a sensor node, it starts to send data packets to the other sensor nodes or a base station which takes time for one minute. Length of data packet shows the total data length of payload of

TOS_Msg. Payload consists of sourceMoteID, lastsampleNum, channel and ECG data. Value of lastsampleNum in consecutive packets can be used to detect the packet-loss that may occur. The difference of the value of lastsampleNum in consecutive packets is a constant value which is equal to the number of data readings in a single packet.

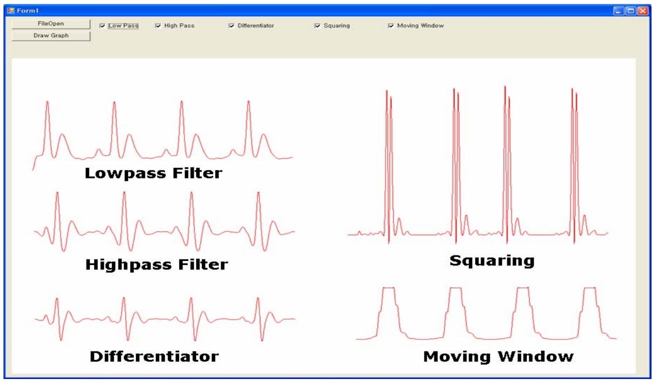

Fig. 5 (a) Step results of QRS complex on sensor node

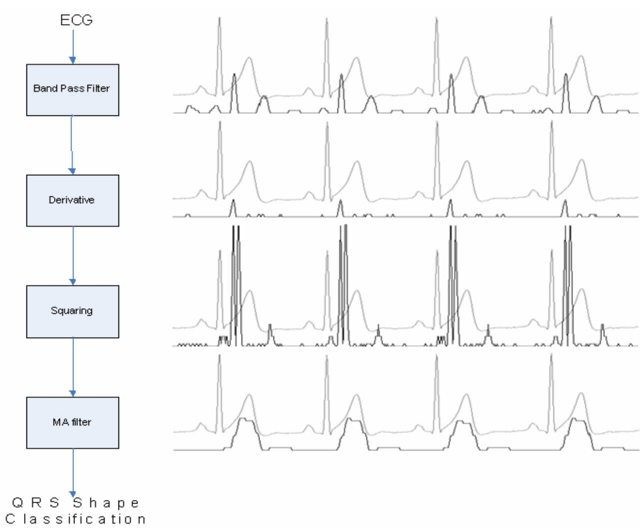

Fig. 5 (b) Step result of QRS complex on server

Further analysis is done on server after receiving data from sensor node. The abnormal ECG graph on server with heart rate of 102bpm is shown in Fig. 6. Firstly it was detected by sensor node and then transfer to the server for further detail analysis. According to the analysis on the server, the possible detected disease is exhibited as ventricular ectopy and then transfer alarm condition to the doctor's PDA which is indicating by red button on the screen and giving alarm.

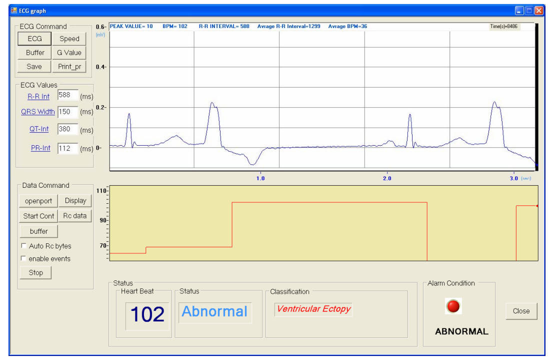

Fig.6 Abnormal ECG graph on server.

IV. CONCLUSIONS

A new approach for ECG signal monitoring using analysis function on sensor node was designed and implemented for u-homecare system of elderly person or patients. The QRS complex of ECG can be detected on a sensor node with limited resources. According to the new approach for ECG analysis on sensor node, we can reduce the data packet overload and save power consumption in wireless sensor network. This method can also reduce data congestion when the number of monitoring patients increases at the server. Based on abnormal ECG activity due to R-R interval and QRS width, the sensor node can transfer ECG data to the server for extended ECG analysis and disease classification. Needed information of abnormal ECG from the server can also be transferred to the doctor's PDA for further diagnostics.

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V. REFERENCES

[1] D. Konstantas, "The Mobihealth Project. IST Project," IST-2001-36006, European Commission: Deliverable 2.6, http://www.mobihealth.org,2004

[2] Victor Shnayder, Bor-rong Chen, Konrad Lorincz, Thaddeus R. F. Fulford-Jones, and Matt Welsh, "Sensor Networks for Medical Care," Harvard University Technical Report TR-08-05, April 2005

[3] Lim, L. and B. Yee, Coach's Companion – "Athlete's Health Monitoring System," University of California,Berkeley: Berkeley.

[4] P.E. Ross, Managing Care through the Air, IEEE Spectrum, December 2004, pp. 14-19.

[5] J.Pan and W.J. Tompkins, "A real-time QRS detection algorithm, " BME-32, pp. 230-236, 1985.

[6] V.X. Afonso,W.J. Tompkins, "ECG Beat Detection Using Filter Banks," IEEE Trans. Biomed. Eng. Vol. 46 No. 2, pp. 192-202, 1999.

[7] MIT-BIH Arrhythmia Database CD-ROM.Available from the Harvard-MIT Division of Health Science and Technology, 1992.

[8] David Gay, Philip Levis, David Culler and Eric Brewer (2003). nesC 1.1 Language Reference Manual. May 2003.

[9] TinyOS at http://www.tinyos.net/.