Packet Traffic Management in Wearable Health Shirt by Irregular Activity Analysis on Sensor Node

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ABSTRACT

This paper describes the packet traffic management of the Ubiquitous Healthcare System. In this system, ECG signal and accelerometer signal is transmitted from a wearable health shirt (WHS) to the base station. However, with the increment of users in this system, traffic over-load issue occurs. The main aim of this paper is to reduce the traffic over-load issue between sensor nodes by only transmitting the required signals to the base station when irregular activities are observed. In order to achieve this, in-network processing is adapted where the process of observation is conducted inside the sensor node of WHS. Results shows that irregular activities such as fall can be detected on real-time inside the sensor node and thus resolves traffic over-load issue.

Keyword

Wearable Health Shirt, Fall detection, Packet Traffic Over-load, Wireless Sensor Network

I. Introduction

Based on a survey conducted in Korea published at year 2010 [1], it is observed that up to 43.4% of the unintentional home injuries in Korea were caused by falling and slip down. Among these injuries, up to 57.1% of injuries were suffered by elderly people with the age of 65 and above. Although 35.3% of the elderly people were fully recovered after treatment; 34.2% of the elderly people still suffered mild handicap after the fall and up to 4% of the elderly people faced death. This survey concludes that falling and slips down poses a high risk for elderly people given the severity of the injuries that causes on them. To reduce the number of severe handicap as well as the death toll, immediate treatment to fallen or slipped elderly people is needed.

Conventionally, all the signals captured is transmitted to the base station for further processing. However, with the increment of the number of users using separate wearable health shirt simultaneously to the same monitoring device, traffic over-load issue arises. This paper focus on how to overcome the traffic over-load issue between sensor nodes. The aim is to develop a real-time fall detection platform with irregular activity analysis on sensor node. This can reduce the data packet overload between sensor nodes by only transmit the ECG and accelerometer signal to the server when irregular activities are detected. With this, immediate attention or treatment can be applied to the patient without delay.

II. Device

Ubiquitous Healthcare System is a system developed by our lab with the main objective to monitor a person health status wirelessly by using wireless sensor network[2]. The ECG signal and accelerometer signals are captured from the patient and transmit to the nearest base station for processing.

There are 3 main structures in this system: wearable health shirt (WHS), base station and monitoring device. The WHS consists an ECG sensor, an accelerometer device (MMA7260Q), an A/D converter (MSP430F1611) and a wireless transceiver (CC2420) as shown in Figure 1. The accelerometer device used in the wearable health shirt is a tri-axis accelerometer device [3]. The sensor node used can be programmed using TinyOS [4] and they operate on low power batteries. At the other end, a base station which is used to receive the transmitted healthcare signals is connected to a computer which acts as a monitoring device. The monitoring device was developed using C# language and is capable of showing the real-time accelerometer signal as well as ECG signal from different users that wears each WHS at the same time.

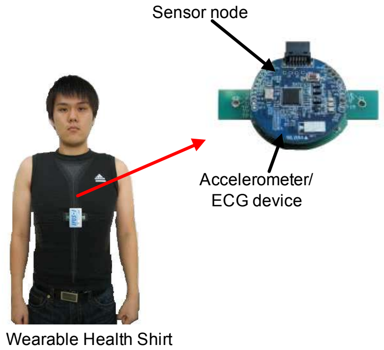

Figure 1. Wearable Health Shirt(WHS)

Ⅲ. Packet Traffic Management

In this paper, the focus is being centered at processing information locally inside the sensor node and sending the end results to a central location. The management of the packet traffic is crucial as the traffic over-load issue will occurs as the number of user using the system increased.

With a sample frequency of 100Hz and each packet transmitting 10 data samples; the monitoring device is expected to receive up to 40 data packets from the WHS in every second. With 4 users using the system simultaneously, the monitoring device is expected to receive up to 160 data packets from the WHS every second. This greatly increase the delivery latency of the data packets and hence, degrade the real-time performance as real-time noise cancellation [5] or data analysis are conducted as the data comes in. Thus, it is more effective to conduct the information processing locally inside the sensor node and only send the data packets to the monitoring system when required.

In this paper, irregular activities analysis algorithm which was developed using nesC programming language running on TinyOS is done inside the sensor node. The NesC component interface for irregular activities analysis application based on TinyOS is shown in figure 2. Once a fall is detected, the ECG signal is then transmitted from the WHS to the base station and alert the medical personnel that the patient have fall.

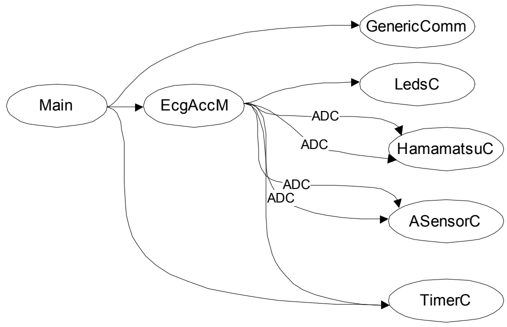

Figure 2. NesC component interface for irregular activities analysis application based on TinyOS

Ⅳ. Irregular Activities Detection

The system implements a fall detection algorithm that processes inside the sensor node. Pre-processing is require before the actual implementation to determine the threshold magnitude for the accelerometer signals. Threshold magnitude can be obtain by performing Root-Mean-Square (RMS) using the equation 1 below:

$$RMS = \sqrt{((Ax\hat{}2\ ) + (Ay\hat{}2\ ) + (Az\hat{}2))} \qquad (1)$$

During the pre-processing, a series of pre-determined actions were conducted which includes: walk, run, pick-up things, kneel down, wake up, stand up (chair), sit down (chair), jump and fall down. Due to security precaution, the fall down action conducted is a slip down action which falls to the back on to a mattress.

Based on the collected data, magnitude threshold is determined and used in the fall detection algorithm shown in figure 3. This fall detection algorithm is performed inside the sensor node. Inside the sensor node, the RMS value is first calculated and if the calculated RMS value is above the threshold magnitude pre-determined, then a fall is suspected. A false alarm detection algorithm is added in to check on the user's chest position after the fall. If a user fall down, the z-axis of the user's accelerometer signal will be above a certain threshold due to the chest position. Once a fall is detected, ECG signal of the patient is sent to the base station and warning message is alerted at the monitoring system to request immediate attention from the medical personnel.

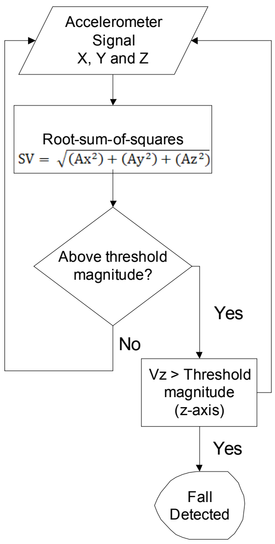

Figure 3. Flow chart of fall detection algorithm

V. Results

Figure 4 shows the box plot chart of the RMS of all the activities described in the previous section. From the chart, it can be noticed that highest RMS recorded is during the fall event, followed by jump and wake up. Thus, a magnitude threshold is determined in between the maximum value of the action “fall down” and “jump”.

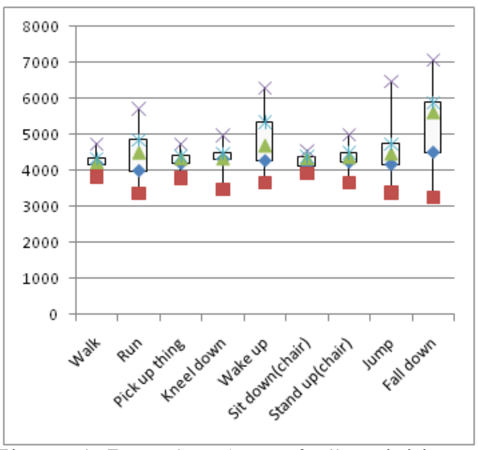

Figure 4. Box plot chart of all activities conducted

For false alarm detection, the magnitude threshold is decided based on the separate value of x-axis, y-axis and z-axis. Figure 5(a) shows the x-axis, y-axis and z-axis when a user is jumping while figure 5(b) shows the condition when a user is falling down. From the figures, it is observed that the both the y-axis and z-axis of falling activity is higher than the jump activity. However, in this paper, the focus on false alarm detection is on the position of the chest with comparison to the ground. Thus, only z-axis signal are taken into consideration for false alarm detection. Another magnitude threshold for z-axis is set based on the data observed.

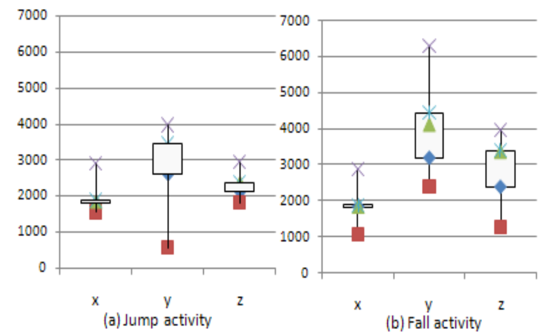

Figure 5. Box plot chart for (a) Jump activity and (b) Fall activity

VI. Conclusion

In this paper, packet traffic management concept is introduced to overcome traffic over-load issue between sensor nodes. Conventionally, all data packets are transmitted to the base station, processed and then monitored in the monitoring device. This has created traffic over-load issue when there are multiple users using the system by sending continuous data packets to the base station every second. In this paper, irregular activities of a patient are processed inside the sensor node and only trigger the ECG signal transmission when an irregular activity is detected. Research shows that by applying this concept, the number of packets received by the base station can be reduced greatly. However, the limitation of performing fall detection algorithm in a single sensor node is due to the processing power of the sensor node. Side effects such as data loss and increase of data latency will happen if the algorithm applied is too complicated and cannot be supported by the processing power of the sensor node.

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