Report of Research Results

Scaling and Deployment of e-Guardian to Eldercare Centers and Single Elderly Homes

Primary Researcher:

Prof. Tan Kok Kiong, Department of Electrical and Computer Engineering

Co-researcher:

Ms Er Poi Voon, Department of Electrical and Computer Engineering, NUS

Aim of Research

Earlier, we have designed and implemented the early prototype for an intelligent health monitoring and alert system (named e-Guardian) for the elderly. e-Guardian allows working people to be alerted of their loved parents' emergencies in the first minute. It is an affordable and effective solution to address the worldwide population aging. In this project, we took it to a significantly improved beta version with initial testbedding results.

e-Guardian takes advantage of a wide range of technologies including wireless sensor networks (WSN), cellular network, Microelectromechanical systems (MEMS), mobile and ubiquitous computing as well as machine learning. The heart of the system is a base station that acts as a gateway between cellular network and ZigBee personal area network. At the elderly's sides are a number of small wearable devices that are capable of automatically detecting accidental falls, inferring simple Activities of Daily Livings (ADLs), measuring body temperatures or even heart rate, etc. During an emergency or an accidental fall, appropriate alert signals will be sent to caregivers and/or family members via SMS.

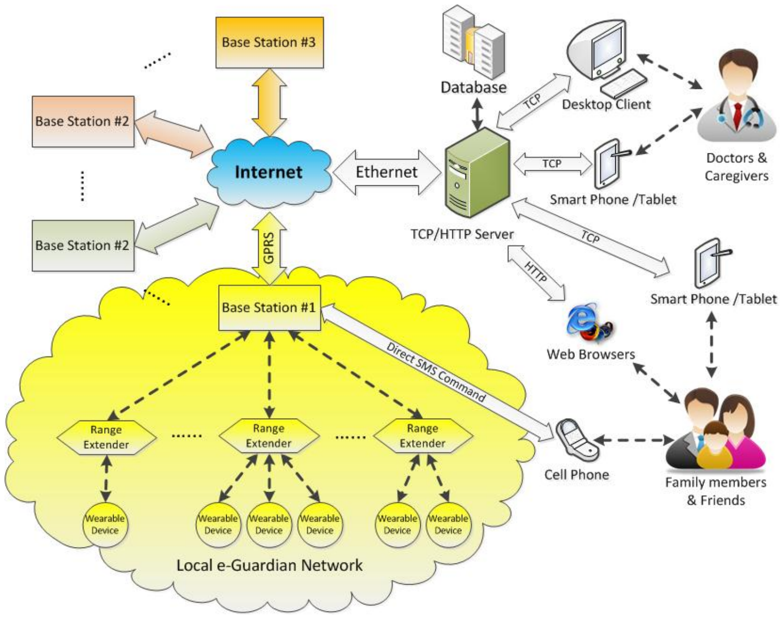

Figure 1: Architecture of e-Guardian

The ZigBee network coverage can be extended via a number of range extenders. e-Guardian is not only suitable for small households but also good for care centers, hospitals or even entire community areas. The ability to scale easily sets e-Guardian apart from contemporary PERS (Personal Emergency Response Systems) which allows seniors to summon help via a direct point-to-point wireless link between a wearable pedant and the home telephone. The point-to-point link restricts the use of PERS to small and medium-sized households only.

Outline and Conclusions of the Research

The project has undergone two prototypes. This MSIGWF grant arrived after the completion of first prototype and has been used as the main source of fund for the second prototype.

The latest prototype consists of a base station, several range extenders and wearable devices.

Base Station

The base station consists of a GSM/GPRS module and a ZigBee System-on-chip module connected via UART. The GSM/GPRS module enables caregivers to interact with the system remotely via either SMS or internet.

The size of a base station is about 10x10x1cm. It is to be powered by the mains.

Figure 2: Prototype of Base Station

Range Extender

The range extenders are powered by the mains too. Their size is about 3x4cm. Wherever there is a ZigBee network dead zone, an additional range extender around that spot is all that is needed.

Figure 3: Prototype of Range Extender

Wearable Device

The current version of wearable devices consists of a distress alert button and a digital MEMS 3-axis accelerometer. The size is about 3x4cm and can easily fit into a watch case. The elderly wearing such devices can either press the button to signal distress or let the device automatically detect falls and other activities. The accelerometer is used to implement a fall detection algorithm and a classifier for activities of daily livings (ADLs).

The wearable device is extremely low power, which can work on a button cell battery continuously for several months. This is empowered not only by the low power nature of ZigBee but also by intelligent designs of the aforementioned algorithms. Both algorithms are interrupt-driven as they take advantage two mains features that are present in digital accelerometers: interrupts and FIFO buffer.

Figure 4: Prototype of Wearable Device

Figure 5: Wearable Device Embedded into a Watch Case

Method of Research & Progression

Development of e-Guardian Notable Features

Distress Alert

When a senior wants to summon help, the elderly could press the distress alert button on a wearable device. This alert will be sent to all caregivers via SMS.

Fall Detection

When a senior falls, a fall alert will be automatically triggered and sent to caregivers.

Conventional fall detection algorithms are based on analog accelerometers which must sample all three axes at a frequency somewhere between 50—250Hz using ADC (Analog to Digital Converter) module. This conventional method not only keeps the host processor constantly busy at sampling all the time but also requires the host processor to examine each piece of data and run a digital signal processing algorithms on the sampled data.

This proposed and implemented fall detection algorithm takes advantage of interrupt and FIFO features of the chosen accelerometer. The algorithm features a finite state machine which only computes upon accelerometer interrupts and does not compute at all when there is no interrupt generated. As a result, the host processor could stay in the sleeping mode as long as possible, thus extra-long battery life is achieved.

ADL Classification

An ADL classification algorithm has been designed on top of the fall detection algorithm, taking advantage of information already computed in the fall detection algorithm. As there is only one accelerometer which is worn on the wrist, the number of identifiable activities is limited to only "Random", "Quite" and "Walk".

Presence Broadcasts

Each wearable device sends out a presence broadcast once every 5 seconds. Neighboring range extenders and the base station could capture such presence broadcasts and evaluate their RSSI (received signal strength indicator) values. The proximity of a wearable device relative to its neighboring range extenders (including the base station) could be approximately evaluated. Presence broadcasts form the foundation of a number of features in e-Guardian, as discussed below.

Location Tracking

The objective is not to construct a 2D or 3D map showing the detailed location of a wearable device at any moment. An easier approach has been taken that e-Guardian only summarize all RSSI values captured by range extenders and the base station and forwards this summary to medical personnels. In large scale deployments such as a rehabilitation center or a hospital, this could help quickly narrow down the search range when emergencies occur.

Context Awareness

1. **Danger Zone Alert**: Certain places at home such as kitchen, bath rooms and toilets are dangerous than others. Staying in those areas more than certain time (configurable) will trigger an alert.
2. **Automatic Night Light**: Poor lighting is one of the prominent reasons for falls among the elderly. Certain range extenders could be equipped with light bulbs and light sensors. When ambient light is poor and if any wearable device is near, the light bulb will turn on automatically.
3. **Automatic Voice Notification**: When deployed in a home environment and also connected to a TCP/HTTP server, information such as weather forecast, important local news can be periodically downloaded. When a senior walks near the base station centered in a home, the base station could play a number of pre-recorded audio messages via an integrated speaker

when seniors are nearby at appropriate time. Audio messages could, for instance, be “good weather for a morning walk”, “avoid outdoor activities because of imminent storms or blizzards”, “time for bed as it is late” or “do not forget to take medications before sleeping”.

Universal Internet Access

A TCP/HTTP server has been implemented so as to enable administrators to manage devices and their corresponding caregivers via a PC client application on any computer with internet access.

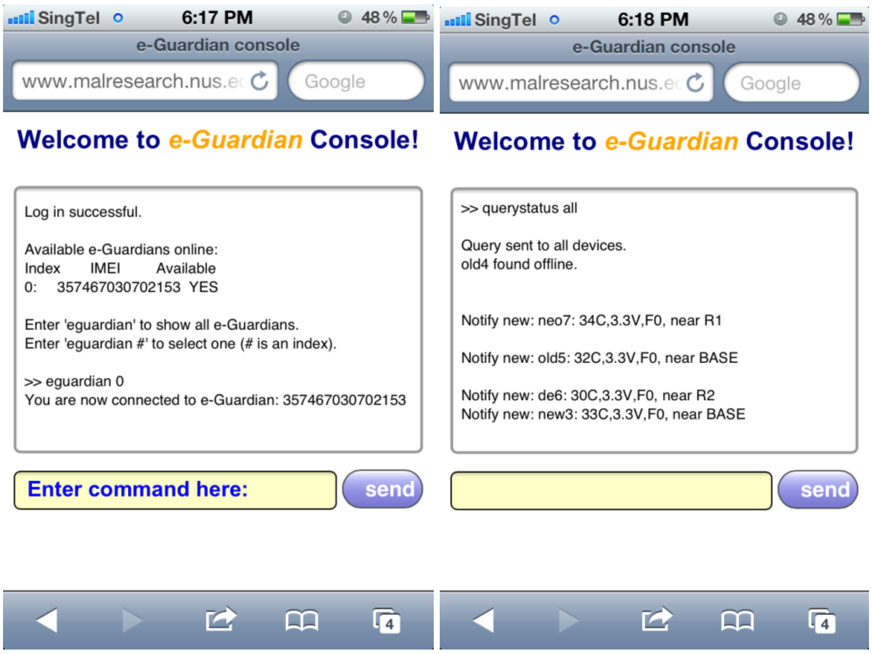

Figure 6: Configuring e-Guardian via iPhone Safari Browser

Other Features

1. The system implements an authentication protocol to allow only authorized wearable devices to join the network.
2. The system is highly secure by implementing an AES-128 encryption algorithm which makes it impossible to be attacked by intruders.
3. Caregivers can query for recent status of the elderly and also set up reminder alerts for medications or physical exercises on time.

Results of Research

Test Bedding

Simulated Falls

Tests of the proposed fall detection algorithm are simulated by four young subjects. Each of them wore a wearable device on his/her left wrist and performed 4 types of activities: (1) walking, (2) walking upstairs, (3) walking downstairs, (4) walking some distance, then sitting down in a chair beside a desk and doing things such as writing, picking up and putting down random objects. Each person performed each activity five times for two minutes each time. Then activities (1), (2), (3) were performed again for five times, but each time with a fall in the middle. The simulated fall were detected with a high rate of success and a false alarm kept to a minimum.

Community Test Bedding at NTUC Eldercare

A trial study was carried out at a daycare centre. The main objective of the trial was to ensure robustness and obtain fall detection accuracies. The eldercare center features a long three-room flat occupying an area of about 50m by 10m. One base station and three range extenders were deployed. Three range extenders are labeled as "rest", "act" and "dine", corresponding to their locations in the rest room, the activity area and the dining room respectively.

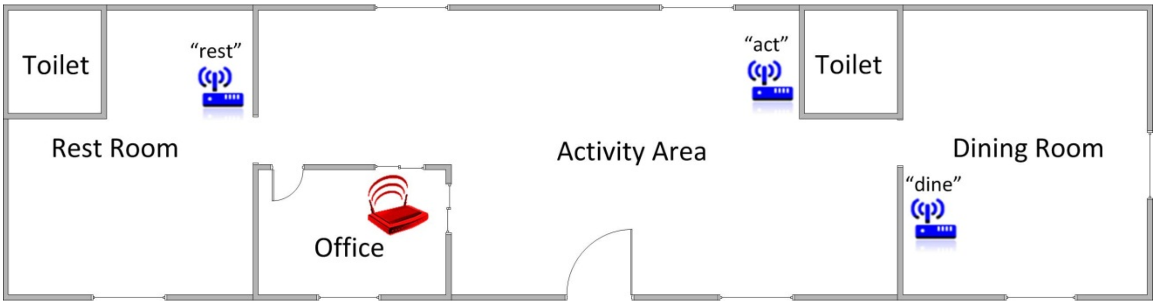

Figure 7: Floor Plan of the Daycare Centre

Figure 8: Deployment of One Base Station and Three Range Extenders at NTUC Eldercare

The trial was done over a period of two months of the period to verify is applicability and sieve out potential issues. Three seniors from the center participated in this study. The three seniors wore wearable devices when they arrived at 9 am and took them off before they left at 6 pm. All wearable devices were powered by Li-ion batteries with a nominal capacity of 150mAh. There were all fully charged before the trial study. The e-Guardian network deployed was robust throughout the study. All wearable devices lasted a full month without recharge.

The false positives detected were comparable to benchmarks as suggested by Bagala et al.[1]. Considering that wrists' movements are more complicated than parts of a torso, this rate of false positives is encouraging.

Future Areas to Take Note of, and Going Forward

Current efforts are geared at further reducing the cost of the setups. Also, the base station is being upgraded to also function as a home health pod to enable telemedicine applications.

[1] Bagalà F, Becker C, Cappello A, Chiari L, Aminian K, et al. (2012) Evaluation of Accelerometer-Based Fall Detection Algorithms on Real-World Falls. PLoS ONE 7(5): e37062. doi:10.1371/journal.pone.0037062

Means of Official Announcement of Research Results

The research results have been published in journal papers and a conference paper was presented at the IASTED International Conference on Engineering and Applied Science in Dec 2013. The work was publicized in the local papers in 2013 and the team has linked up to a number of government bodies and community service bodies to carry the work to the mass.