Unobtrusive Wireless Monitoring System for Assisted Living and Improving the Wellbeing of Elderly People

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Abstract. A novel system to unobtrusively monitor the wellbeing of elderly people based on their activity patterns is presented. The system uses a wireless ZigBee network to monitor the electrical usage in a subject’s home and then sends this data to an Apache server via HTTP from a GPRS unit. The data is logged in a MySQL database where pattern analysis is used to identify periods of significant inactivity. When such an event is identified designated contacts are notified by text message. For subjects requiring higher levels of monitoring a portable health monitor can be integrated incorporating a fall detector and panic button to inform of emergency situations.

1. Introduction

People are always concerned about the welfare of their loved ones, especially in their later years and if they are living alone. Thus there exists a need to monitor the well-being of these elderly people while still allowing them to retain their independence. A summary of current technology solutions to monitoring wellbeing is presented in Table 1. An ideal system should be as unobtrusive to the person in question as possible. Such a system is presented here where sensor nodes monitor the electrical usage in a subject’s home and transmit the data to a server and database. Pattern recognition algorithms check for periods of inactivity and inform predefined contacts of such events.

| COMPANY           | SOLUTION OFFERED                                      | TECHNOLOGY               |
|-------------------|-------------------------------------------------------|--------------------------|
| GE QuietCare[1]   | 24/7 detection and warning system                     | motion detection system  |
| Emergency Response (CARE SERVICE)[2] | alarm button, fall detect, flood detect, temperature, gas and smoke detect, motion | series of sensors, motion detectors |
| HealthSense[3]    | panic alarm pendant, motion, bed and toilet sensors solution, blood pressure, weight scales, pulse oximeters, networked cameras | series of sensors         |

Table 1 Existing Solutions
2. Functionality
For those with good health and living alone, the system developed utilizes low powered sensor nodes to monitor electrical usage in a subject’s home and transmit using wireless protocols to a server and database. Once in the database, pattern recognition algorithms will check for periods of inactivity and if detected, the system will then inform predefined contacts that the subject may be in danger. The novelty of this system is that, once installed, the subject has to do nothing more than their normal daily routine and do not need to interact with the system in any way, putting it out of sight and mind. Caregivers or family members can then check the status of the subject by logging in to the secure website provided where graphs of activity can be viewed.

For those with health concerns, a health monitoring device can also be utilized which transmits the vital signs of the subject (pulse rate, body temperature) to the database along with a fall detector and panic button status. This device, while being more obtrusive offers a more complete picture of the health and reasons for inactivity in a person. The panic button gives some control to the user in terms of informing of an emergency while the fall detector would be potentially lifesaving to an individual in their later years.

3. System Architecture

![Figure 1 System Architecture](image)

The system architecture as seen in Figure 1 is made up of the domestic Wireless Sensor Network (WSN), web-server and the user interface.

3.1. Domestic WSN
The domestic WSN consists of a ZigBee low power network with a single coordinator node and point to point star network to monitoring nodes. The prototype uses the PICDEMZ development boards [4] and a custom application node has also been developed. The monitoring nodes are designated as power/activity monitors or health monitors as shown in Figure 1. In the power monitor node three current transformers are used to monitor the power present in three targeted household circuits and are sampled every minute. Every ten minutes the stored data is transmitted to the coordinator node via the ZigBee protocol [5][6]. In the health monitoring node temperature and pulse rate are continuously logged and fall events, detected using an accelerometer and panic button events can also send notification of an emergency situation to the coordinator[7][8].

The coordinator receives data every ten minutes from the energy monitor and on an event from the health monitor. The data is sent with a timestamp to a central web-server via a GPRS connection. The coordinator will also store phone numbers for carer’s of the elderly person and will notify a care giver if it receives an emergency event notification.
3.2. Web-server
The web-server is an Apache server with activity and health packets received from the domestic WSN via HTTP from a GPRS module. The received data is processed using PHP/Java scripts to extract the required data fields and inserts the data into associated data tables in a MySQL database. The coordinator node ID is used to establish from which customer the data originated. The customer table in the database is polled to extract the customer name and used to derive the table names in which the received data is to be placed.

In the parser, consecutive readings are compared to identify changes in power consumption. Periods with no change are deemed inactive periods while periods with changes greater than a threshold are tagged as an active period. A column in the database is populated with an active/inactive depending on this comparison. This column is used later when determining the activity patterns of subjects.

3.3. User Interface
The user interface operates by remotely accessing the web-server using PHP/Java scripts to graphically display and report on subject’s activity. The user interface provides a user friendly method of efficiently monitoring the activity/inactivity of a large number of remote subjects.

In addition, a Java program continually polls the database extracting all subjects on a system then polls through the database to find their most recent activity. The program checks to see if there has been activity in the morning, and if inactivity is detected after a certain time, a message is sent to their given contact numbers. The program also polls the activity database throughout the day to determine if there has been inactivity. If there has been no activity for a period of time, comparisons are made statistically with a previous number of days for the same time period to determine if the inactivity is unusual. Any unusual events or inactivity will result in a message to the user’s carer and/or contact numbers that have been given.

4. System Test
A prototype system has been developed including a full end-to-end data monitoring function. Development efforts have concentrated on:
- optimising the performance of the domestic WSN
- reliable data transfer to the Web-server
- activity/inactivity analysis routines

A power profile of the power monitoring node was measured to evaluate the power consumption and derive the life expectancy of the battery powered node. The power profile is shown in Figure 2. For the timing outlined above the node powered from three 2300mAh AA batteries would yield a node lifetime of 754 days which can be seen in the Node Life Expectancy table below (Table 2).

The code used for the energy monitor was deployed and tested on three different platforms, the PICDEMZ development board, a designed node based on the PICDEMZ with reduced peripherals and a PIC18F4620 microcontroller placed on a bread board. The major difference between the three platforms is current drawn in sleep mode, due to varying peripherals attached to the PIC18F4620 microcontroller. The resulting node lifetime, for each platform, can be seen in Table 2.
Node Life Expectancy for Three 2300 mAh AA Batteries

| Node                          | Life Expectancy (Days) |
|-------------------------------|------------------------|
| **PICDEM Z**                  | 235                    |
| **Fabricated Node**           | 169                    |
| **Bread-Board (Radio On 1.6 seconds)** | 754                  |

Table 2 Node Life Expectancy

The domestic electrical supply consists of a 50Hz signal at 230VAC; our chosen circuits are sampled using an appropriate rated current transformer for the given circuit depending on the load. As the PIC microcontroller can only read positive values from the sensor via the ADC, a sampling period of 1mS for 20 samples per circuit is used in order to reliably reconstruct the sampled AC signal coming from the current transformer. Figure 3 below shows a graph of a number of samples for a single circuit. The sine waves were produced using a signal generator for validation purposes.
The peak values obtained are used to determine the power in each circuit. At this sampling period we can reliably determine the peak value to over 96% accuracy. This was tested and proved by varying the peak to peak voltages being input to the ADC on the PIC microcontroller. The expected ADC values for each voltage were calculated and the detected values recorded. The results are plotted below in Figure 4 and a linear response can be observed.

![Figure 4 Reconstruction of 50Hz Sine Wave](image)

### 50Hz Sine Wave

| Volts   | Expected | Observed |
|---------|----------|----------|
| 0.1V pk-pk | 15.5     | 16       |
| 0.2V pk-pk | 25       | 25       |
| 0.3V pk-pk | 46.5     | 44       |
| 0.4V pk-pk | 62       | 63       |
| 0.5V pk-pk | 77.5     | 75       |
| 0.6V pk-pk | 93       | 90       |
| 0.7V pk-pk | 108.5    | 109      |
| 0.8V pk-pk | 124      | 128      |
| 0.9V pk-pk | 139.5    | 141      |
| 1V pk-pk  | 155      | 153      |

![Figure 3 Graph of Electricity Usage for One Day on Circuit 2 (Kitchen)](image)

Figure 3 above graphs one day electricity usage for circuit 2 (kitchen). Inactive periods are easily identified. It is intended that if there is continued inactivity during the day of over 4 hours, previous data for the same time period will be analyzed i.e. day-1, day-2,…day-7 etc to identify if inactivity is unusual. Various statistical algorithms are in place that analyze the activity count and electricity usage variances and deviations and perform data correlations of previous day’s activity to determine and build a pattern model. If unusual behavior is detected a message will be sent to care givers and/or family. Currently field data obtained is limited and sustained testing and increased data could lead to improved and more focused analysis and result sets.
Messages will also be sent if morning inactivity is detected. Data is also sampled from circuit 1 (shower) and circuit 3 (lighting) to retrieve a more detailed activity outlook.

5. Future Work

The complete system functionality has been established from domestic WSN to storing the data in a database at a central server. Increased Network Stability Testing of the system needs to be carried out to improve and remove any potential weak points. Additional System Security, introducing security measures such as data encryption at the WSN and upgrading from HTTP to HTTPs for transmitting the data to the central server could be implemented to better secure the overall system.

Additional data from deploying the system in a number of household test environments would validate the stability of the entire system and generate data to be used to improve our activity pattern analysis algorithms.

6. Conclusion

A complete system to unobtrusively monitor the wellbeing of elderly people living alone has been presented. The system uses a domestic WSN to monitor electricity usage of the subject’s home with this data being regularly transmitted to a remote web-server. The historical electricity data is analysed on a continual basis and when a period of inactivity is detected a message is sent to family and carers. Data has been presented on the domestic WSN performance and from initial trials where inactivity has been identified using a simple activity/inactivity algorithm. A system to notify care-givers when inactivity is identified or in an emergency event is incorporated both at domestic and remote user interface levels.
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