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Ambient Assisted Living using Sensor and Mobile Technologies for Elderly People

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Abstract: The emergence of ambient-assisted living (AAL) tools is a blessing for the human society, nowadays, with the innovative smart sensors and mobile technologies. These ICT-based products, services and systems are increasing the quality of life, autonomy, participation in social life, skills and employability of older adults, and reducing the costs of health and social care. Moreover, monitoring the daily routines and activities of elderly people and thus help them to avoid being unwell subside the load on the patient monitoring. In this paper we propose and design a system which includes smart sensors and mobile technologies to monitor daily routines of elderly people and to report the career any atypical event. Our designed AAL Communication system not only provides efficient monitoring services but also opens new commercial opportunities through the use of information and communication technology. In addition, the proposed system is robust, economical, and secured.

Keywords: AAL, APK, WLAN, Android SQLite.

1. INTRODUCTION

Aging is an opportunity for people to enjoy longer and better life after their retirements. Nation-level demographic trends caused by an aging population, however, raise obstacles to the opportunity, particularly financial and environmental issues. Nevertheless, societies value their older citizens because of the wisdom and wealth gathered from their life experiences. Hence, taking care of elderly people is a very important and challenging issue where communication and information technologies can play an important role.

Ambient Assisted Living (AAL) [1,7,37] communications are a way to address these issues by creating better life conditions for the aged and for people in recovery, and by creating new commercial opportunities through the use of information and communication technology. AAL uses ambient technologies to enable new products, services, and processes that help to provide safe, healthy, lives for the aged and recovering. With the integration of a set of technologies, AAL environments focus on the development of an integrated approach for the areas of health monitoring and therapy support at home, and mobile health, wellness and fitness. The systems are intended for remote patient supervision using multi parameter biosensors and communication networks, and health & wellness monitoring such as blood pressure monitoring, cardiovascular monitoring, diabetes monitoring etc. indirectly.

Besides the health and wellness monitoring, it is very crucial to monitor the daily routines and activities of elderly people and thus help them to avoid being unwell. Consequently, daily routine monitoring implicitly subside the load on the patient monitoring. Appliances of everyday life such as cooking stove, heating and cooling system, microwave oven etc. can be monitored and these appliances can provide feedbacks whether an elderly person has used that in an appropriate way. Otherwise a message can be transferred by the system to the caretaker warning about an individual. This automated daily routing activity monitoring system may help a caretaker to take care of a large number of elderly people to ensure their daily routines are going alright.

In this paper we have proposed a framework of such a system described above. The proposed framework monitors an elderly person's daily routine and activities and this information is transmitted over the mobile network to the career. Moreover, we demonstrate a sample example which is developed as a prototype of the proposed framework. The proposed model monitors the cooking stove status from an android mobile phone, which also allows the elderly people safety assurance from catch fire.

The rest of the paper is organized as follows: in Section 2 we describe how the ambient assisted living technologies with the help of mobile technology can ease the task of careers to take care a large number of elderly people. In Section 3 we describe the framework of the proposed system which exploits the AAL technologies with mobile technologies. This section describes the component of the framework, architecture of the model, choice of mobile operating systems and the architecture of the user database for the system. The implementation of the proposed system is described in Section 4. Section 5 elaborates on the features of the proposed framework. Finally, in Section 6 we draw the conclusion and discuss about the future work.

2. AAL WITH MOBILE TECHNOLOGY

The aim for the research in Ambient Assisted Living (AAL) is to improve the quality of life, especially for the elderly people. Smart sensors and their networks will positively contribute to independent living and quality of life for elderly individuals as they can monitor and sense abrupt situations quickly. With appropriate protocols and settings, the smart sensors are able to identify any

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particular event. These sensor detected data will be analyzed automatically and will be sent to the caretaker of the disabled or elderly.

Mobile networks can help in this regard to disseminate the information quickly and reliably to the careers. Moreover today, most smart phones are equipped with various sensors such as accelerometer, gyroscope, proximity sensor, and global positioning system (GPS), which can also be used for detecting user activity and mobility.

Overall, a smart home can be designed to make the living place of elderly more tractable. A smart home is a home augmented with various types of sensors and actuators. Detailed context information can be obtained by analyzing and fusing various types of sensor data [21]. Most smart homes utilize such knowledge for automation and providing more comfort for the residents, as well as for assessing the cognitive and physical health of the residents.

Various projects on smart home design have already been undertaken aiming at assisted living. For example, CASAS [21] project at Washington State University provides a non-invasive assistive environment for dementia patients at home. The "Aging in Place" project at the University of Missouri aims to provide a long-term care model for seniors in terms of supportive health [22]. Elite care is an assisted living facility equipped with sensors to monitor indicators such as time in bed, bodyweight, and sleep restlessness using various sensors [23]. The Aware Home project at Georgia Tech [24], [25] employs a variety of sensors such as smart floor sensors, as well as assistive robots for monitoring and helping elderly. Other notable smart home testbeds include DOMUS [26] at the University de Sherbrooke, and *House_n* project at the MIT [27]. Other smart home projects include iDorm [33], Grenoble Health Smart Home [29], Gloucester Smart House [34], PROSAFE [30], ENABLE [35], and CareLab [28]. The *Welfare Techno House* project, which measured indicators such as ECG, body weight, and urinary volume using sensors placed in the bathroom and bathtub [32]. The Ubiquitous Home project [31] is another smart home project in Japan, which uses passive infrared (PIR) sensors, cameras, microphones, pressure sensors, and radiofrequency identification (RFID) technology for monitoring the older adults. For a more thorough review of the smart home technology, refer to related survey papers [36].

Aligned with the aforementioned projects, in this paper, we describe a system which is designed with the combination of smart sensor nodes, mobile network. The system mainly monitor elderly people for their daily routine such as breakfast, lunch and dinner event by checking the appliances of daily routine like stove top, microwave oven etc, For example, in a situation when an elderly person does not take the breakfast, or the cook-top is turned on for a long amount of time, an alarm is sent to the career using an Android mobile phone. A graphical user interface (GUI) pops up and shows information about the elderly person. In another scenario, if the room temperature is too or too cold, an alarm occurs in the career's mobile phone. An example system is shown in figure 1, where an Android mobile is being used to monitor the live status of a cooktop system.

Fig 1: Android mobile is showing stove top status

3. ROUTINE ACTIVITY MONITORING USING AAL WITH MOBILE TECHNOLOGY

Designing AAL technologies is growing significantly in the developed countries such as Australia, United States and in Europe. If the mass production can be achieved, the cost of the product will be affordable for many people. We propose to use mobile technologies because the integrated circuit Wireless Local Area Network (WLAN) with operational Android Application Package (APK) is supposed to find a very good position in markets both domestically and internationally. This system can be integrated with an existing electrically equipment in a smart home automation system. The selling of the software and the hardware will increase the manufacturers' revenue as well. A sample interface in the Android phone to check the stove top is depicted in figure 2.

Figure 2: A stove top interface in an Android mobile phone

In addition, the proposed system may be used by the manufacturers of different appliances for smart homes. The challenging part of the system design would

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understand the manufacturer's existing system and then implementing a microcontroller [3] based WLAN circuit, which will integrate with the electrically based system. By a Local Interconnect Network (LIN) [4] bus communication, a microcontroller based WLAN circuit is able to detect the electrical equipments and the WLAN [5] sends a notification event to a mobile device. A LIN bus is a one wire communication, which is commonly used in the automobile sector. The system design requires designing both hardware and software.

Several microcontrollers and electronics hardware are available to design the proposed system. To keep the cost low, it is important to figure out appropriate but cheaper electronics component. Obviously a costly microcontroller provides a wide variety of functionality but that increases the cost of the product. After designing circuit, the developer can replicate the circuit into the printed circuit board [2], later on a drilling tools is efficient to plug-in a microcontroller and the Wireless Local Area Network (WLAN) into the board. This board sends a notification event to the Android mobile device. In the later sections we show how an Android mobile device fetches messages from the mail server. In the following sub sections we discuss different components and options for the proposed system.

3.1 Choice of mobile operating system

The best business smart phones have sharp displays, high-quality builds, and long battery life. But there is a lot more to a smart phone than hardware. Ultimately, what makes a phone great is the software it runs on. There are three major operating systems available on smart phones today: iOS from Apple, Android from Google, and Windows Phone from Microsoft. Each offers a distinctive spin on the smart phones experience – but which one is more suitable for the AAL is the question to ask. Android, iOS and Windows Phone have a lot in common, and each provides a solid platform for the users to run the applications they need. But each also has one-of-a-kind, productivity-boosting features. Windows Phone boasts a user-friendly interface and handy features such as Live Tiles. Android is the most customizable, making it a good fit for power users. Meanwhile, iOS offers a simple but powerful interface that is backed up by the best overall selection of apps.

In this project we choose Androd mobiles for the System. Android mobile phones are combatively cheaper than other smart phones such as iPhones. It has been found that almost an Android mobile phone priced 200 to 400 dollars is able to run Assistant Ambient Living (AAL) project APK files. The Android operating system was developed by a consortium of almost thirty smart phone companies. As the Android supports multi-core programming, a program developed on the Android runs faster and provides a very good reliability. Android offers an environment for programs with multi threads to run concurrently without free race of condition.

In addition, an Android SQLite database is efficient to hold all valuable user information (Figure 3). A SQLite database is a server-less database, much more efficient and flexible. It's relational schema efficient to do insert, delete, update and searching operation in the database. It is simpler than MySQL database [1, 6].

Figure 3: User search

3.2 Component of the framework

The proposed system runs on an Android based platform (Figure 4). This allows flexible and adaptable service that can be integrated on an existing system on the same platform. In a dual core Android mobile multiple threads or multiple Android APKS can run in parallel. If the end user or the caretaker needs any extensive feature, the developer is able to enhance that feature in the existing system.

- A sensor is plugged into the wireless network. This sensor automatically checks for an event triggered in the cook stove. For example, when an elderly person turns on the cooktop, a micro controller WLAN module will send an event message to the mail server. The message contains embedded information of the cook stove status and sensors information. A micro-controller WLAN module has knowledge about the name of email account.
- An Android background program runs all the time in an Android operating system. A task manager is able to open or close the program. Every five or ten minutes of interval, the program checks for new emails from the mail server (Figure 5). A Java mail API provides several protocols to download emails from the mail server. , The post office protocol (POP) downloads new emails from the mail server and stores then on the SD card. A SQLite database is used to store data in the SD Card.
- Work-flow section: A parser algorithm reads the message content word by word. It defines the user ID, the MAC address, the cook stove status, the room temperature and stores the fragmented data into the SQLite database. The parser algorithm identifies starting and ending time of the cook stove as well. Context utilization is a decision level model. This model always checks if any user's stove top is turned on for a longer time. If this time is greater than the threshold limit, an alarm occurs on the Android mobile device.

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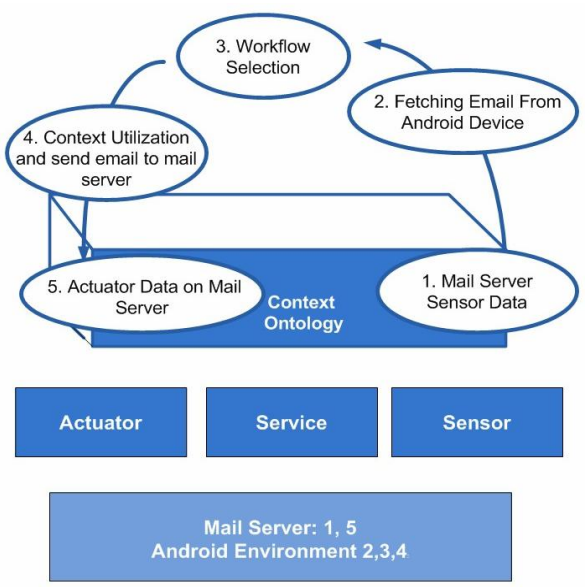

Figure 4: Assistant Ambient Living Context Flow Diagram [26]

- Another scenario of context utilization is as follows: if an elderly person does not take the breakfast, the program can identify that the elderly people's stove top had no event during the morning time. In this situation, an alarm goes to the Android mobile device. In the same way the system can keep track of an elderly person's lunch and dinner events too. Or if an elderly person forgets to shut down the stove top, an alarm goes to the mobile device. The career then would be able to shutdown the stove top by clicking the shutdown button. A message will then be sent from the mobile device to the mail server, an actuator will shut down the stove top after downloading the email from the mail server.

Figure 5: Settings Time

3.3 Architecture of the model

The architecture of the proposed system consists of three layers: abstract layer, android application logic layer, and the concrete layer. In the abstract layer (Figure 6) the user is able to register a set of services. The user or client achieves many context label services from the application browser such as navigation services, services from telephone servers and other Android services. The Android application logic layer negotiates in between of an abstract layer and concrete layer. A concrete layer defines a concrete algorithm implementation. In the concrete layer a bundle takes arguments from the context service registry and performs the algorithm event over user behavior and stores data in the database or fetch data from the database [7].

Each of the user or elderly people's cooking time is different from each other. A program is able to make a decision from user behavior data. Elderly people's takes breakfast from 8:30 to 10:00 o'clock, lunch time from 13:00 to 14:00 o'clock and dinner time from 20:00 to 21:00 o'clock. In case of any event that had performed in this time, an alarm will occur on his android mobile phone and a user graphical interface will pop up. This interface will show that elderly people's did not perform morning or lunch or dinner event and call him. Furthermore, an Android user is able to call him and able to call a navigation service during the driving mode.

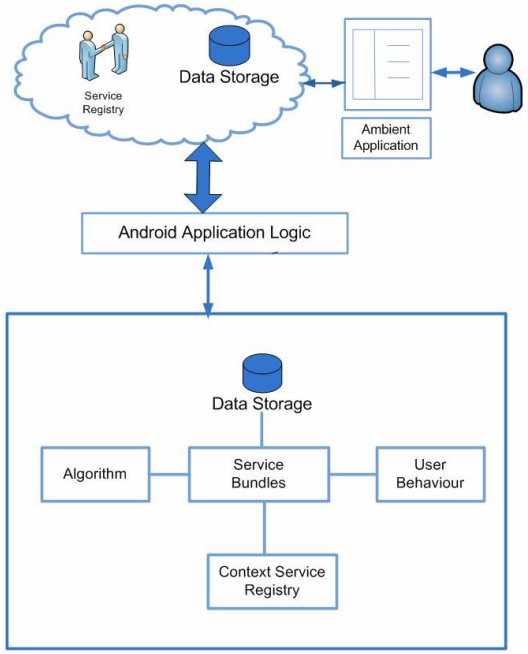

Figure 6: Architecture of Assistant Ambient Living [7]

The following figure (Figure 7), explains how the context manager interacts with the infrastructure sensing manager [8]. The infrastructure sensing manager directly negotiates with a logic algorithm. A logic algorithm is used to fetch messages, parse messages and the event handler stores the data into the database. The event handler is dealing with a SQLite database to read and write operations, in addition to thread programming.

The infrastructure sensing manager is running always on the Android task manager. A background program acts as a infrastructure sensing manager. The program listens to any new emails on the mail server. When a new email's arrives at the mail server, the program fetches the email and it parses the message content of the email to find the data. Each email message contents has information such as

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the user ID, the MAC ID, the cook stove status, the oven temperature, and the fridge temperature etc.

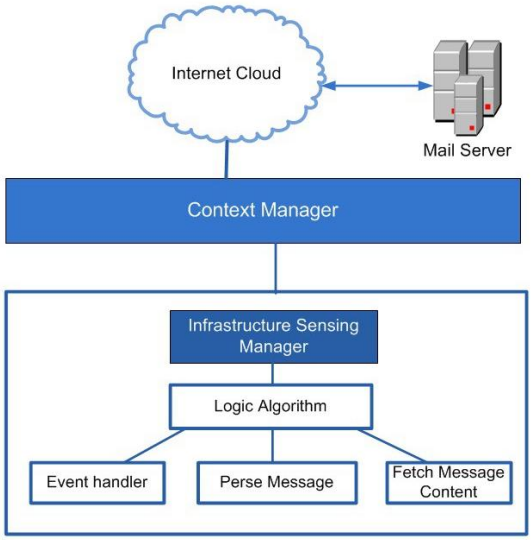

Figure 7: Context Manager of Assistant Ambient Living [7]

3.4 Database Architecture

Android introduces the persistent SQLite database library. SQLite offers a powerful SQL database library that provides a robust persistence layer. It's relational database allows the user to submit insert, delete, update and get queries, while the user is creating a modifying scheme. SQLite is simply a scaled down version of MySQL, PostgreSQL, and other popular relational database systems. It is entirely self-contained and does not require a server. However, the transactions can still use the standard SQL language for executing queries. SQLite is self-contained and executable, extremely efficient, flexible, and accessible by a wide variety of programming languages across a wide variety of platforms, including Android itself [13].

The entity relationship data model (E-R) is used as a tool communications between database designers. The E-R model is used to construct conceptual data model, which is a representation of the structure of the database. E-R model represents data of an organization or for a business area. The E-R model is expressed in terms of entities in the business arena. The output of the conceptual data model is expressed by the entity relationship model. The major construction of E-R model has entities, relationships, and associated attributes. Each of the entities has several types, among them: person, place, object, event, and concept. Each of the entities has a list of attributes. Attributes values are identified by primary key and candidate key. In Figure 8, the entity "table check time" has a primary key. Similar the entities "table protocol", "table alarm time", "table event" have candidate key, that is meaning those entity have several primary keys. When the table is doing relational operation during the runtime, the relational algebra has to satisfy the primary and the candidate keys attributes values. In the figure, entity "table check time" has one to one relationship with the entity "table protocol". The entity "table protocol" has a binary relationship with the entities "table event" and the "table alarm time" [10-12].

Database contents are changing over period of time. For example, database contains information about stove top status. Every update status is a relationship in between of two or three entities. When an Android mobile phone will download any new messages after that it will parse the information, next it will store data into the entity "table protocol". At the same time the entity "table alarm time" updates the corresponding older person corresponding event 1 and next event is going to 0. For example, an elderly people took breakfast normally 8:00 to 10:30, if he took breakfast in that interval time, then the entity "table event" is going to insert the morning event with 1 and the lunch event with 0. The entity "table check time" is a control entity that checks out how different behavior fits together, next program will store every user events from the entity "table event". The entity "table check time" will hold the last update time from the mail server, either it gets new message from the mail server or not.

To fetch email from the mail server, the android program needs user name, password. The entity "Fetching Email Server" holds all of the valuable information. The entity "Table Alarm Event" has one to one relationship with the entity "User Information". Similarly the entity "User Information" has unary relationship with the entity "User Contact". Every certain time interval entity "Table alarm event" checks every individual older person morning event - lunch event - dinner event boolean attribute, if any attribute has null value, next it show up an alarm event on the android mobile phone and then it insert the Boolean value 1 at the corresponding event. For the next time, the program will not perform any alarm when it will be retrieved 1 [8- 14].

4. IMPLEMENTATION OF THE PROPOSED FRAMEWORK

When the stove top event is changed by the elderly people, for example either the cook stove is on or off; at that time a global system mobile (GSM) wireless local area network (WLAN) module detects that change of event and sends a message to the mail server containing an eight bit random number (Figure 10). This number is used for security reason. This prototype idea is coming from symmetric cryptography, where the sender knows the encryption key. But, in this context messages are not encrypted. Only the random number is used to protect the system from bad persons and the user cannot hack or corrupt the cook stove activity. When a good user or nurse mobile phone will fetch an email, at that time the database will update starting a time event, if the cook stove status is on [19].

If the event status is true for a long time then it excesses to the threshold value or limit. In this situation, the mobile phone will give an attention or vibration that someone has opened the cook stove for a long time. In this situation, a nurse would like to shutdown the cook stove and she or he will turn off the cook stove by a shut down button click event. So a security issue can be implemented.

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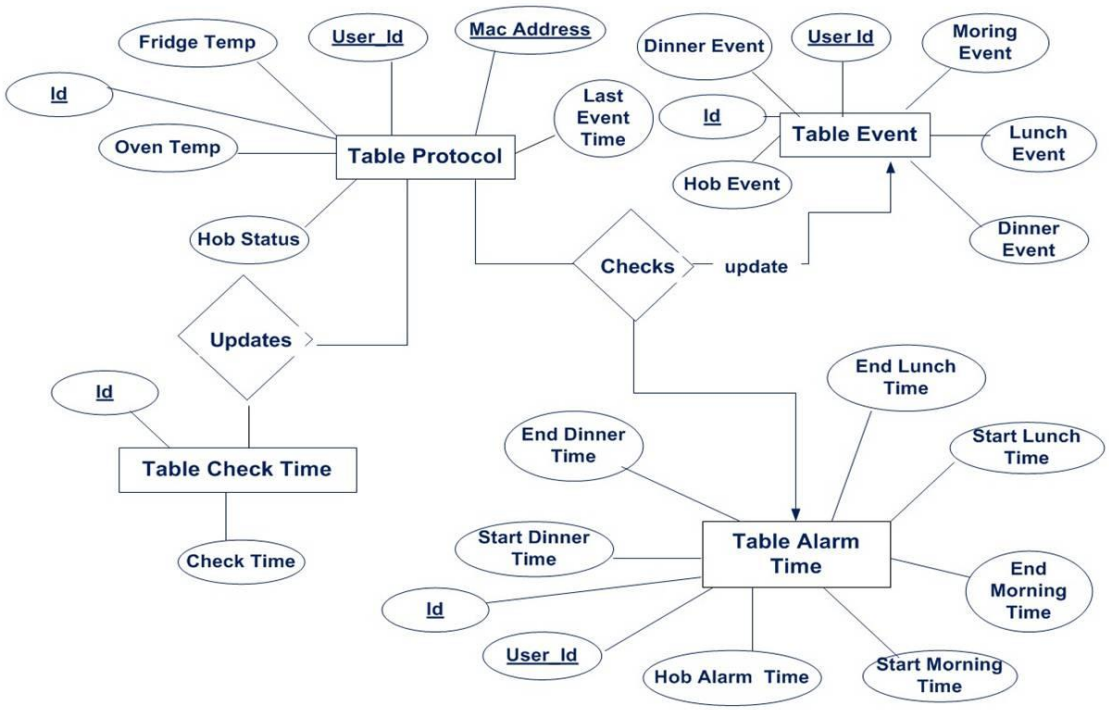

Figure 8: Entity Model Diagram 1

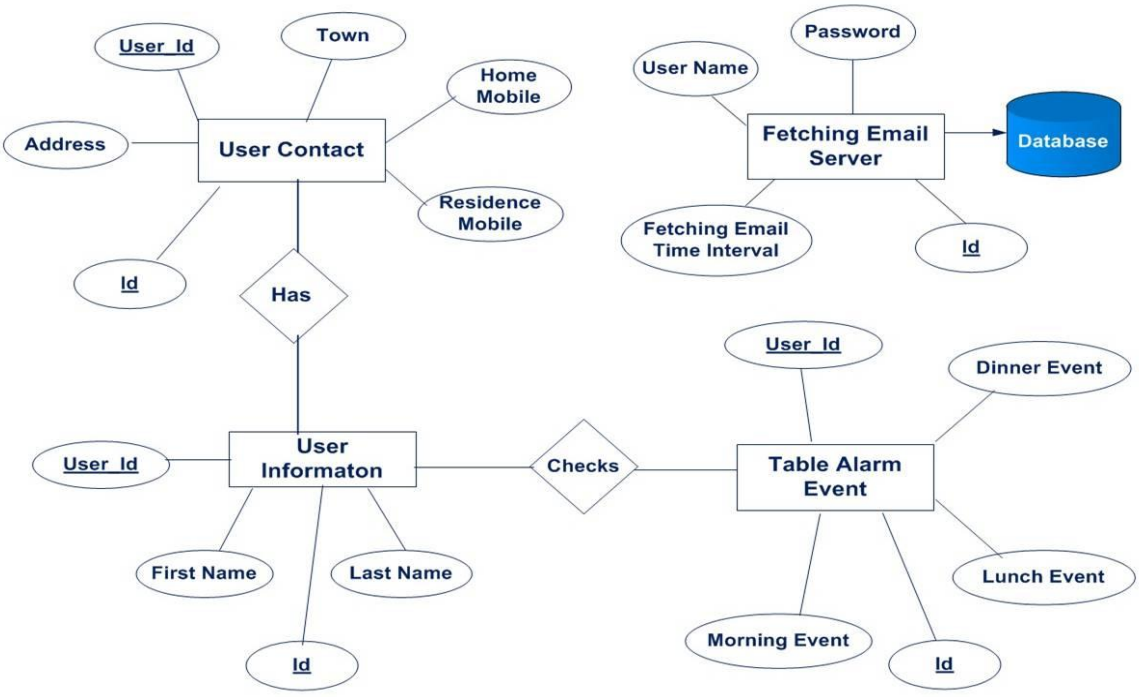

Figure 9: Entity Model Diagram 2

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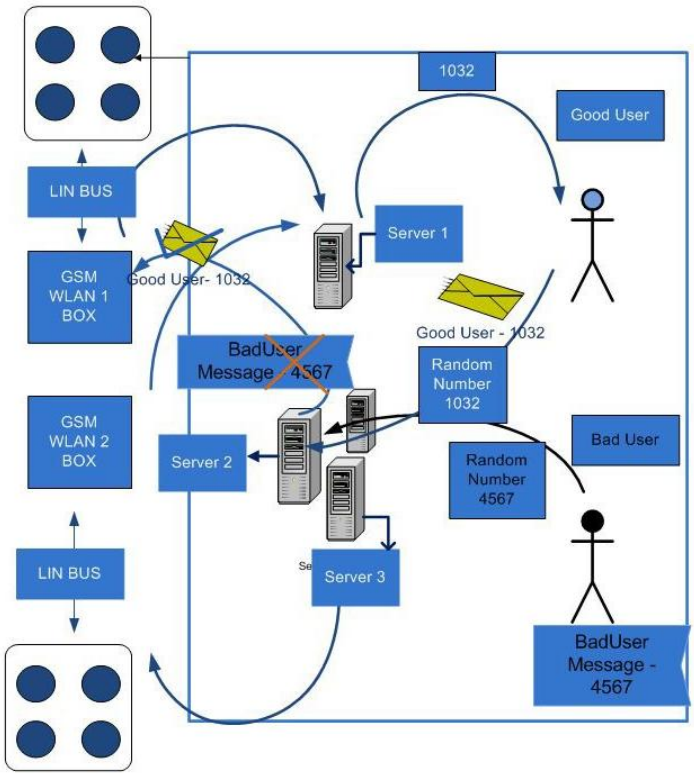

Figure 10: Random Number Functionality on Alarm Hob [19]

Running an Android program will send a shutdown message command to the mail server including a random number. Here, a wireless local area network (WLAN) module is listening to a message from the server, if program gets a message from the mail server and it will check out, then it will match the random number of the corresponding user from a read only memory (ROM). When all of the conditions are fulfilled on the program activity flow chart at that time, the micro controller of the cook stove will do the shut down event. Normally, the LIN bus will do shut down connection, in that time cook stove will become shut down.

For example, if an intruder will not be able to hack the microcontroller event for any ill purpose such as to shut down the cook stove, s/he will not be able to do it because of the lack of the random number corresponding to the user. . In this situation message will become discarded by the WLAN module. That is why the random number is used in the WLAN module for every event.

Another important aspect is that a single mail server is used for every WLAN module; all of the WLAN modules send their update status or start status to the common mail server. On the other hand, every WLAN module has its individual mail account for receiving email. When an Android mobile device wants to communicate with the user's WLAN module, the mobile device sends an event corresponding WLAN module mail server account. One mail server is common for every WLAN module and they send event notification messages to that server. Each of the WLAN modules has individual mail server account to fetch mails from the Android devices.

The system also allows the career to monitor the users at any particular time. The system allows the career to see the user's name, including the stove top status, the fridge temperature, and the oven temperature etc. Usually the program retrieves data from SQLite database, which resides in the Android standard disk SD card folder. In case of an event takes place in the user's WLAN module, the database is updated. The career is also able to set each of the user's cooking event time, for example breakfast, lunch and dinner time. That event's threshold times are also set for each individual user so that if a user does not take breakfast, the career gets an alert message in the mobile device.

5. FEATURES OF THE PROPOSED FRAMEWORK

Mistakes in software development will continue to be made, no matter how carefully the software is built, or the failure occur that the way of engineering. Most of the software engineer learns from their failure.

The goal of the software developer team is to build robust software, which will run free of error. AAL system that has demonstrated the ability to recover gracefully from the whole range of exception inputs with the situations in a given environment.

In a software development most of the codes are enclosed under the check point programming and the exception handler code makes the software robust. The program will able run non-stop without free of error. In case of any feature does not work, in that time it will show error message and the program will jump to the next phase without terminating the program.

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In case of any inconsistency event at the android mobile phone, it will show up alarm vibration. There is very little opportunity for false alarm. For example, suddenly the stove top or any sensor is showing null functionality, at that time false alarm could occur. That kind of condition is very rare. The heart beat message resolve that problem. On a certain time interval the sensors will send the heart beat message to the android mobile phone. In case of any sensor null functional condition, the android mobile phone will show up the null functional sensor, furthermore the android mobile phone user will able to turn off the sensor from the corresponding older person profile and he will able to recover the hardware later on.

The whole infrastructure is based on symmetric random number functionality. A hacker will unable to shutdown the stove top or the sensors remotely. Similarly the hackers will unable to misguide the android mobile user. If the android mobile phone or the stove top microcontroller figures out unwanted random number message, immediately it will discard the message and the android mobile phone will identify the hacker attacks. Next, the android mobile phone and the microcontroller will use another mail account to communicate each other. Sometimes, it is difficult to change currently running micro-controller email account. The third party Wi-Fi based black box will able to change currently running microcontroller input email account parameter.

With an android mobile phone, the career is able to maintain sensors' information of around twenty-five patients. Every user's sensor behavior is different from each other. An efficient multi-thread program are able maintain all of the functionality without free of error. Every sensor plug-in into the micro-controller based Wi-Fi chip. The board cost around 20 euro, which is affordable for every middle class family in the developed country.

At this moment, the android mobile phone will able to monitor three to five sensors information's. In future it will able to monitor much sensor information too. In this development, SQLite database can hold up to twenty sensor information. The developer will have to invoke the new sensor information from the SQLite database to the android graphical user interface [1, 3-8, 13- 15].

6. CONCLUSION

In this paper we describe a framework with implementation to monitor elderly people. Our system includes ubiquitous computing and sensing, ubiquitous communication, and intelligent user interfaces. The systems' integrates ubiquitous computing and sensing technologies with the common everyday objects like stove top, refrigerator, air-conditions, and uses the advanced mobile technologies to send crucial information to the career. The system can be modified to enables inter-object communications using wireless and ad-hoc networking, and this will significantly increase the efficiency throughout AAL systems.

Our designed AAL Communication system not only provides efficient monitoring services but also opens new commercial opportunities through the use of information and communication technology. AAL technologies are growing significantly in many countries. If the mass production can be achieved, the cost of the product will be affordable for many people. The integrated circuit Wireless Local Area Network (WLAN) with operational Android Application Package (APK) is supposed to find a very good position in markets both domestically and internationally. This system can be integrated with an existing electrically equipment in a smart home automation system.

In addition, the proposed system may be used by the manufacturers of different appliances for smart homes. The challenging part of the system design would understand the manufacturer's existing system and then implementing a microcontroller based WLAN circuit, which will integrate with the electrically based system.

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