Re-using old cellphones for IoT applications

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Abstract: In today's world smartphones are the most used electronic device as they come with many capabilities that makes everyday life easier. The downside is that smartphones have very short life span and gets damaged easily, hence overtime they get discarded, which adds onto an existing problem of e-waste. Although thrown away, smartphones' integrated circuits includes components which can be still re-used for other technologies. This project presents a way in which discarding of electronic components without re-use can be combated by making developments in the emerging IoT technology by re-use of smartphone components. To achieve this objective an Android App that requires no use interface and uses only Bluetooth and Wi-Fi components was developed. The App is responsible for giving web capabilities to a maximum of seven Bluetooth enabled sensors, so that the sensors can store their data on a cloud database.

Keywords: Smartphone, Android, Arduino, IoT, App

1. Introduction

Smartphones are one of the most used devices in today's world. Over the years cell phones have developed so much from just making calls and receiving messages. Today's cell phones have added capabilities like connecting to the internet, sending e-mails and viewing and taking pictures, it is for these reasons they are called smartphones. Smartphones comes with embedded chipset that allows carrying out the above mentioned capabilities, such as connecting to the internet. The systems of smartphone are called analog/mixed-signal system-on-chip (AMS-SoC) and these boards have in them mobile connectivity and cellular components which are responsible for the communication of smartphones and also chipsets that executes the system and application software. So today a smartphone is equivalent to a handheld computer and most people rely on it to connect and upload data/information onto the cloud. Sadly with their usefulness, smartphones have a very short life span and every now and then consumers are faced with having to get new ones. The damage to the smartphone could be because of a defective component inside or broken peripheral devices (e.g. touchscreen) that the phone uses to communicate with the end-user. The other reason consumers get new phones is because smartphone technology is becoming sophisticated as time goes by, companies who are manufacturing semiconductor devices are constantly trying to improve their products (chipsets) to be better, faster, more integrated and be able to handle large amount of data, hence there is always a need to get these up-to-date devices [1] [2].

With the increase in smartphone technology there is also a new technology that is emerging called the Internet-of-Things (IoT). The IoT is the network of physical objects that are embedded with electronics, sensors and network connectivity that enables these objects to collect data and upload it to the cloud. The IoT is increasingly being used for many applications around the world, and it has been estimated that by 2020 IoT will consist of about 50 billion objects all connected together . IoT applications are either machine-to-machine, in which objects are connected to each other without any interface, or they use computers or smartphone for interface between the sensors and the internet [3] [4].

Re-using e-waste material for IoT applications instead of discarding it will lead to a solution that is beneficial. The communication components in smartphones are able to carry and send the amount of data that is collected by IoT devices and send it over to the cloud, instead of smartphones being thrown to a pile of e-waste as new technology emerges. This provides an opportunity for electrical and electronic engineers to use their skills and knowledge to combat the fast growing problem of large amounts of e-waste being dumped. Recycling of cell phones will help combat the scarcity of rare-earth minerals, in that the components of discarded devices are re-used for other applications and the available raw materials will be used to manufacture new devices in the future. The other possibility is to start a second-hand market and appliance repair industry in where certain components are being sold to interested parties and also the life span of the devices can be increased in this manner [1]. For these reasons the cost of using IoT applications will be cut down significantly instead of manufacturing PC Boards (PCB) every time an object needs to be connected to the cloud.

2. Objectives

As many people tend to get rid of their old smartphones if they are no longer usable or fashionable, this can lead to increasing e-waste. One mechanism to reduce this e-waste is to re-use some of the functioning components of these devices. To make these devices useful after they are no longer in use their communication components will be put to use and this will help alleviate the problem of discarding of electronic devices (smartphones in this project) without re-use.

The applications of IoT depend on sensors to send data over the cloud. The communication components of the smartphones will be used to develop and build a wireless network system. The network system will be used to transmit the data that has been collected from Bluetooth enabled devices over the cloud. To be able to get the communication system to work and function as required, the processor of the smartphone must be able to send commands to the communication chips. The commands of the processor will be compiled using the SDK development environment (example Android Studio) [5] by developing a none user-interface Application on the underlying OS, this is to remove the complexity at the user end in situations the phone is badly damaged.

3. Methodology

In designing the wireless network system the identified had to be analysed in detail. Following that the problem was determined by looking at issues, requirements and constraints that come with the implementation of the problem solution. The issues and constraints identified and also the requirement specifications which affects the projects were technical, quality and performance, financial, social, legal, safety, environmental and usability. This problem analysis phase makes it simple when designing the wireless network system.

A literature review was then conducted investigating the current state of technology in IoT applications and the re-use of smartphones. The literature review showed that most of the work around IoT only uses smartphone for apps that are used by end-users. The use of Android phones is used in wearable devices. The wearable devices are made for sporting and health care services. Wearable devices come as bracelets and/or as a watch that monitors the performance of the body, like measuring the heart rate or body temperature. Weghorn [6] shows how an ANT+ and Bluetooth LTE are being used to communicate and analyse data using an Android phone. Mandula [7] showed the realisation of a smart home automation using the Arduino board and an Android mobile App, this home automation system uses Bluetooth for indoor and Ethernet for outdoor environment. Here the commands are given from the Android App to the Arduino board to switch the home appliances. The investigated existing technologies rely on using integrated circuits like Raspberry pi and Arduino as gateways between IoT devices and the cloud. Using these integrated circuits requires that one purchase extra components like the Bluetooth and/or Ethernet module to allow connectivity [6] [7].

Finally a design was done with three alternative designs, the three designs were evaluated using the requirement specifications and the best design meeting the specifications was chosen.

4. Technology Description

The wireless network system is made up of an Android smartphone, Bluetooth enabled sensors and internet cloud. An Android App was developed which takes information collected from the sensor and stores that information on an online database. The information on the database can now be accessed from any remote place using any internet enabled device.

Figure 1 and 2 below are flow charts that shows how the App works.

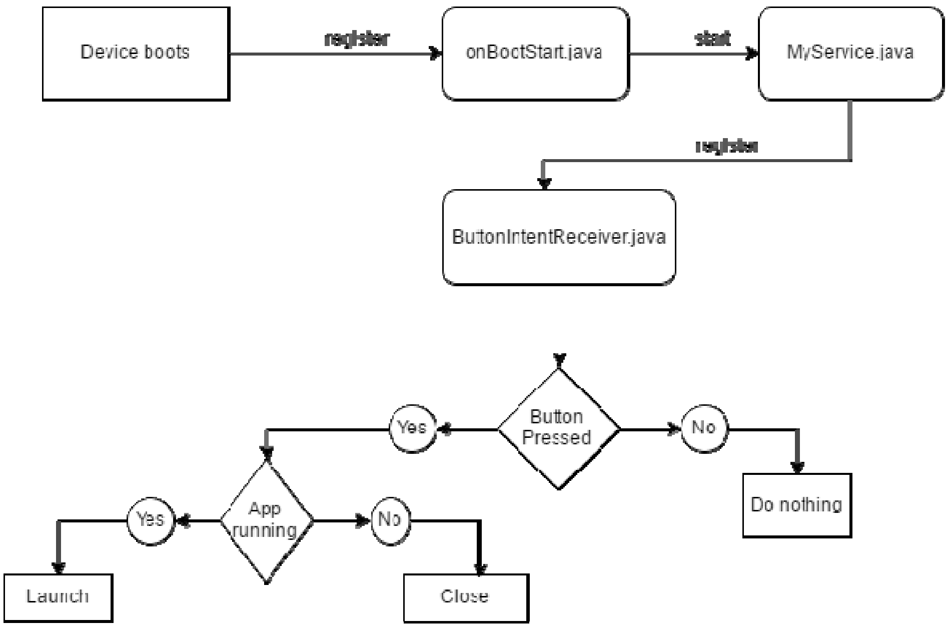

Figure 1: Setup on Boot flow chart

Figure 1 is used is the algorithm used to start the App when the device boot or when restarted. When the device boots the App detects the boot, the onBootStart.java is then started. The onBootStart.java is responsible for starting the MyService.java which is responsible for running the App on the Background. Inside MyService.java a ButtonIntentReceiver.java is registered which is responsible for button press. The button press is responsible for launching and closing the App.

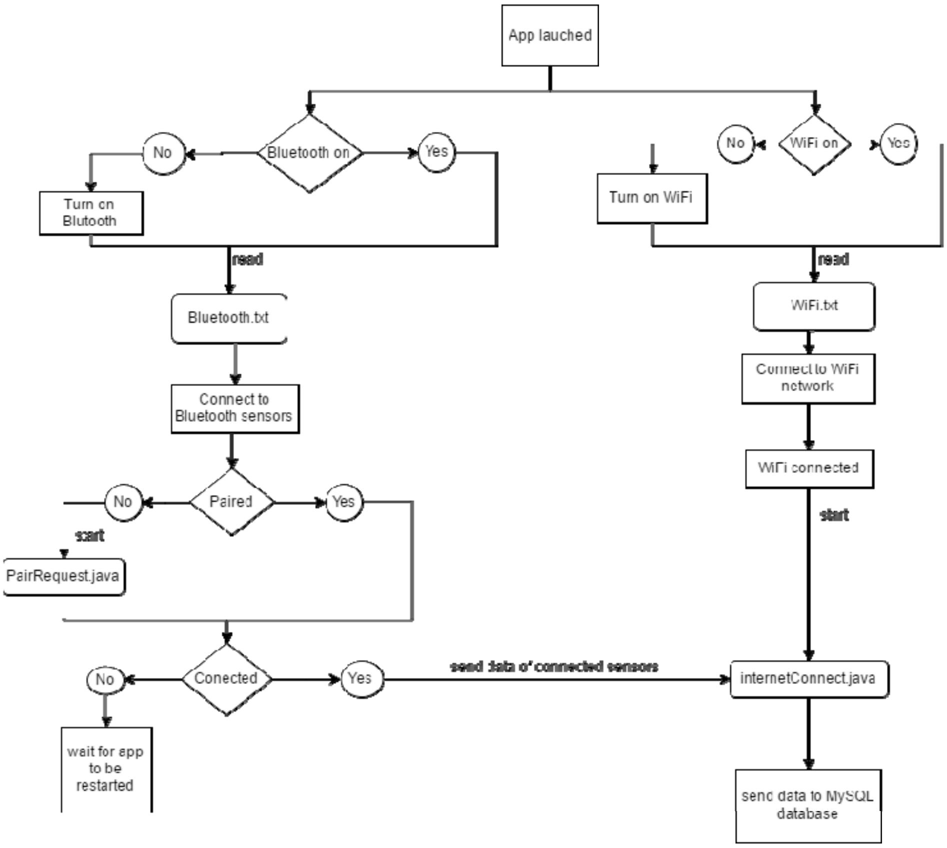

Figure 2: Bluetooth and Wi-Fi Connectivity Flow Chart

Figure 2 is the algorithms of the App responsible for connectivity and data transfer of the wireless network system. The Bluetooth side reads Bluetooth address that the system is to connect to from Bluetooth.txt. The App then checks if these devices are paired, if they are not paired the App automatically pairs with these devices using a hard coded password.

The Wi-Fi side also reads the Wi-Fi address the system wants to connect to from WiFi.txt file. The WiFi.txt has Wi-Fi addresses, AES encrypted password of the corresponding to the address and the security type.

Once the Bluetooth and Wi-Fi connections have been established, the information from the sensors is sent and stored in MySQL database online. The information on MySQL database is made available to the end-user through a website created using PHP and HTML.

5. Developments

Initially the plan was to purchase ready Bluetooth sensors, which are hard to find in local electronics. Knowledge and skills of electronics were used to design the Bluetooth enabled sensors that will work with the network system.

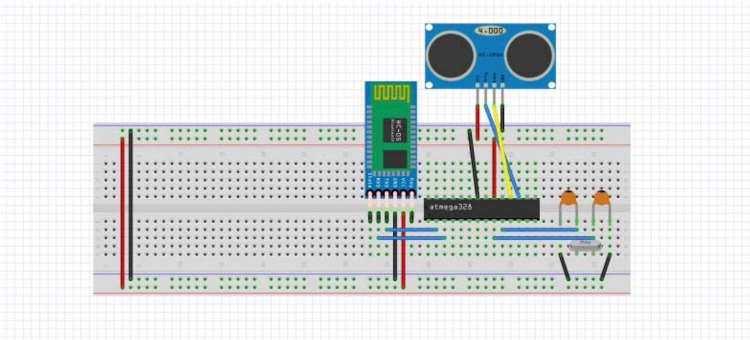

Figure 3: Bluetooth enabled ultrasonic sensor

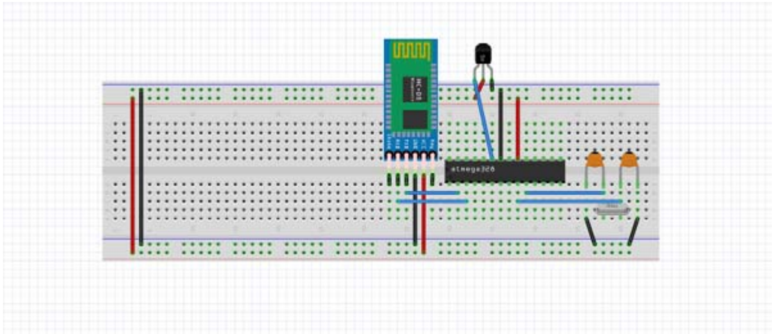

Figure 4: Bluetooth enabled temperature sensor

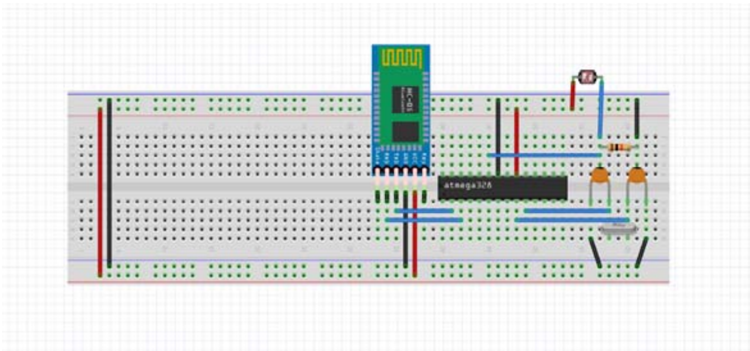

Figure 5: Bluetooth enabled LDR sensor

Figures 3, 4 and 5 shows three Bluetooth enabled sensors that were used for the wireless network system. The sensors were programmed using Arduino software. The App code had to be integrated with the sensors code such that the information form the sensors can be interpreted by the App. Since Bluetooth can form a piconet (connect to up to 7 devices), the App was made such that it has separate links for each sensors, in this way a collision of information from different sensors was avoided.

On building the Arduino sensors there was an integration problem between the Bluetooth module of the Arduino and the Android App written. Arduino uses a function called print() to the send data using the Bluetooth port. On receiving data on the Android App the data was corrupted and not accurate, for example on the temperature sensor instead of sending 33.17 read by the sensor, the information would be captured as 33 first and then .17 second on the Android App which are two different data sets on the App side. It seemed that the Arduino was failing to send the data read as one byte array and the android App kept on getting wrong values. To solve this problem the Arduino sensors where programmed so that each data transferred is terminated by a # to separate different data sets and on the Android side the data sets received from the Arduino are concatenated until a # is received, on receiving a # the concatenated data is sent over to the internet. This makes the information received form each sensor reliable.

6. Results

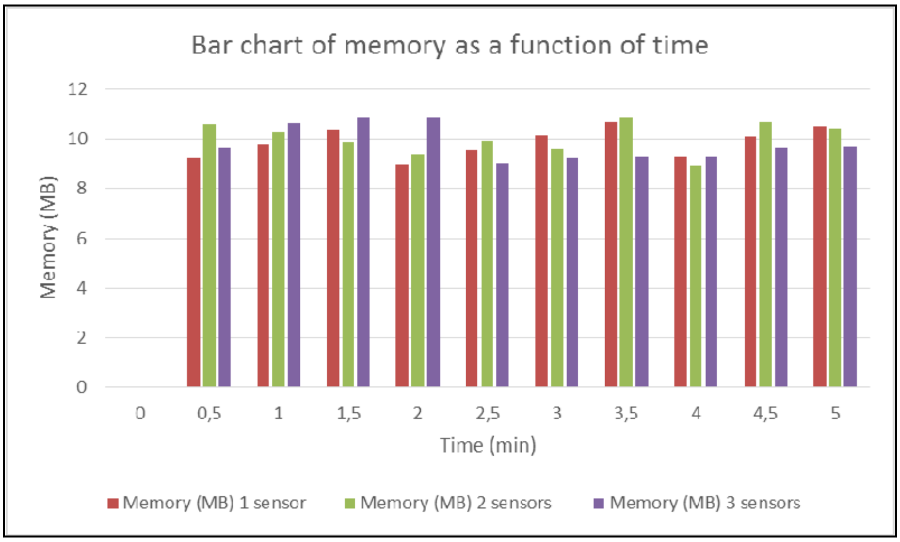

Figure 6: Memory as a function of time

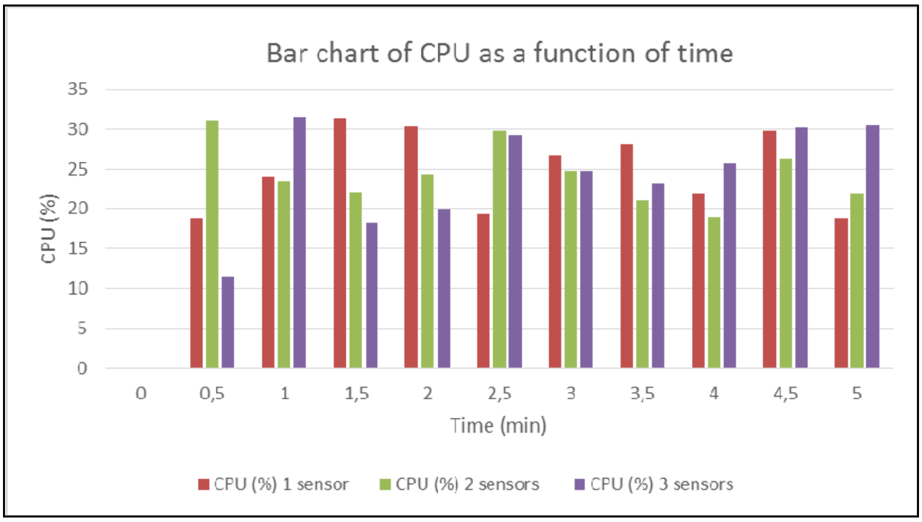

Figure 7: CPU % as a function of time

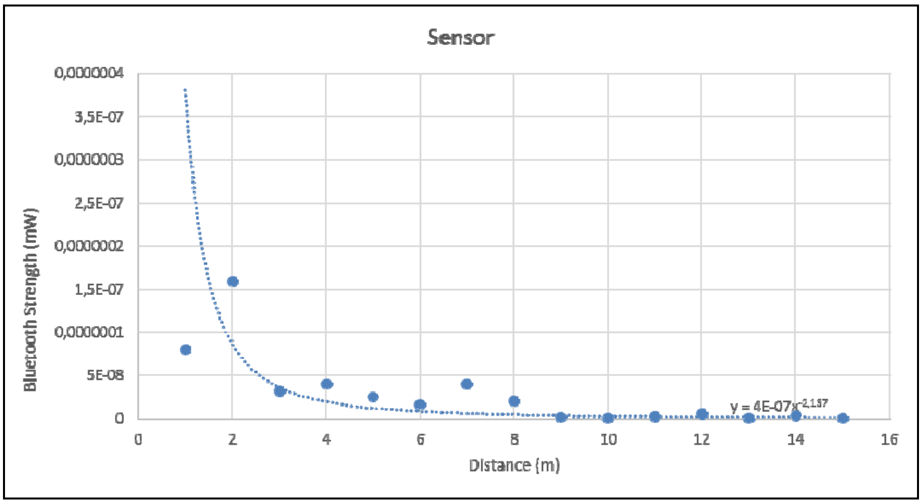

Figure 8: Bluetooth strength as a function of distance

Figure 6 shows that for 1 sensor connected the phone memory used by the App fluctuates between 8.96 and 10.72 MB. For 2 sensors connected the memory fluctuates between 8.92 and 10.88 MB. When 3 sensors are connected the memory fluctuates between 9.03 and 10.87 MB. These results shows the memory used by the App is independent of the number of sensors connected. Figure 6 shows that the memory allocated to the App is almost constant and vary with a maximum fluctuation of 1.76 MB as time increases. This results shows that even if the maximum number of sensors i.e. 7, could be connected the memory used up by the App would still be the same.

Figure 7 shows too much variation when one, two and three sensor are connected. Here there is no linear or obvious relationship between the numbers of sensors connected and the CPU % the App uses. The results shows that the CPU of the App does not particularly depend on the number of sensor the App is connected to but rather it depends on the amount of data the sensors send to be processed by the App.

Furthermore the Memory allocated to the App and CPU that the App uses depends on the RAM and CPU of the phone/ device used. The higher the device's RAM the higher the memory allocated to the App and the higher the device's CPU less CPU is used by the App.

The strength of the Bluetooth decrease with the square of distance and the sensors fail to connect to the App at distances more than 10m shown on Figure 8.

On capturing data, the App is able to successful store data online with error percentage of 5.26%.

7. Business Benefits

The main of the objective of the project is to re-use of electronic devices by cutting down discarding. The implementation of this project on a large scale will have a huge impact on the economy. Instead of discarding the smartphones they will be re-used for the applications of IoT, which often require a network system on an integrated circuit. Hence costs will be cut down, instead of spending money on integrated circuits; smartphones will be re-used as network systems for IoT applications.

Also the wireless system is energy efficient, the sensor uses Bluetooth which uses only small energy and each sensor is powered with 5V which is fairly reasonable. The feature of the system is important since energy management is one of the problem being faced.

8. Conclusions

The main objective of the achieved by developing a wireless network system using an Android App, sensors and internet cloud. The wireless network; gives web and storage capabilities to sensors, works with Android devices of version 4 and higher, doesn't require user interface with the App, connection within 10m and works with up to 7 sensors. Sensor information is available from to the sensor by use of a website.

The shortcomings is that the App doesn't have error handling methods, which makes it prone to crash in the events of errors occurring. Crashes will shut down the App completely and the device needs to be started. Crash times can lead to valuable data loss.

Recommendations and future work to add to the project is to add error handling methods, add hubs to the network system, allow for commands to be sent from the web back to the sensors and implement M2M (machine to machine) communication.

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