School of Electrical & Telecom Engineering
TELE4121
Thesis B Report

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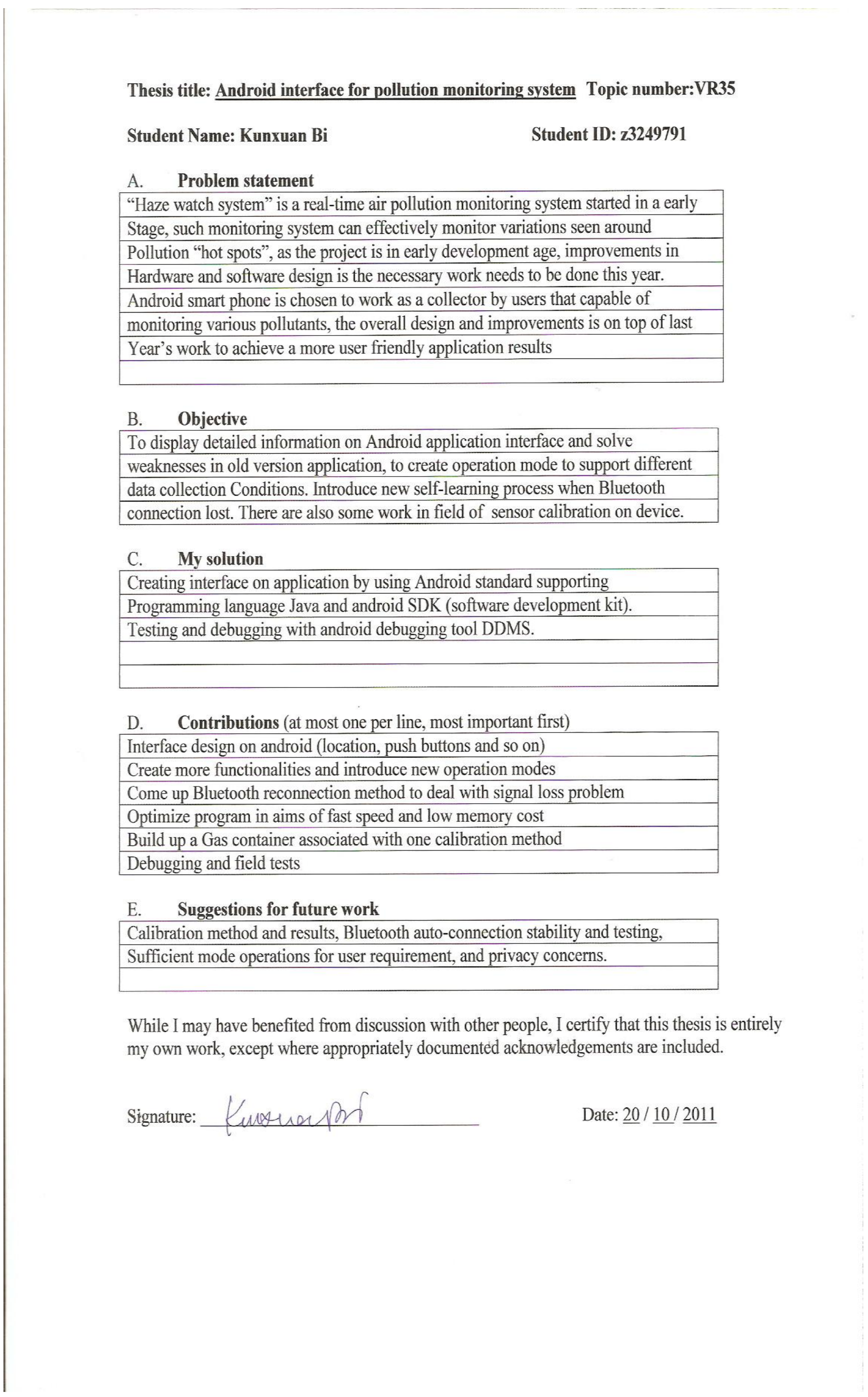
"Android interface for pollution monitoring system"

Abstract:

Australians consistently rank air pollution as a major environmental concern. The state of our air is an important factor in the quality of life among Australian cities. It affects the health of the community and directly influences the sustainability of our lifestyles and production methods. Although Australia's air quality is better than many other comparable countries, it is still important to take actions on to ensure that air quality is protected into the future. Small improvements can achieve benefits for human health and wellbeing.

In this report, we introduce a 'Haze Watch System' that previous year thesis students designed and implemented. This design achieved in collecting air pollution readings, and worked at a higher spatial resolution compare to fixed-site pollution monitoring systems and enables individuals to monitor their personal daily exposures, based on readings retrieved via various applications connect to the system. This project is currently running in its early stage, it is expected that further refinement would be carried out in the future.

This article focuses on the key component of our work together with my partner Dawei Lu in the area of android interface for pollution monitoring system. Detailed design explanations of the Android interface for the monitoring system will be explained and discussed.



Thesis title: Android interface for pollution monitoring system Topic number:VR35

Student Name: Kunxuan Bi **Student ID: z3249791**

A. **Problem statement**

"Haze watch system" is a real-time air pollution monitoring system started in a early
Stage, such monitoring system can effectively monitor variations seen around
Pollution "hot spots", as the project is in early development age, improvements in
Hardware and software design is the necessary work needs to be done this year.
Android smart phone is chosen to work as a collector by users that capable of
monitoring various pollutants, the overall design and improvements is on top of last
Year's work to achieve a more user friendly application results

B. **Objective**

To display detailed information on Android application interface and solve
weaknesses in old version application, to create operation mode to support different
data collection Conditions. Introduce new self-learning process when Bluetooth
connection lost. There are also some work in field of sensor calibration on device.

C. **My solution**

Creating interface on application by using Android standard supporting
Programming language Java and android SDK (software development kit).
Testing and debugging with android debugging tool DDMS.

D. **Contributions** (at most one per line, most important first)

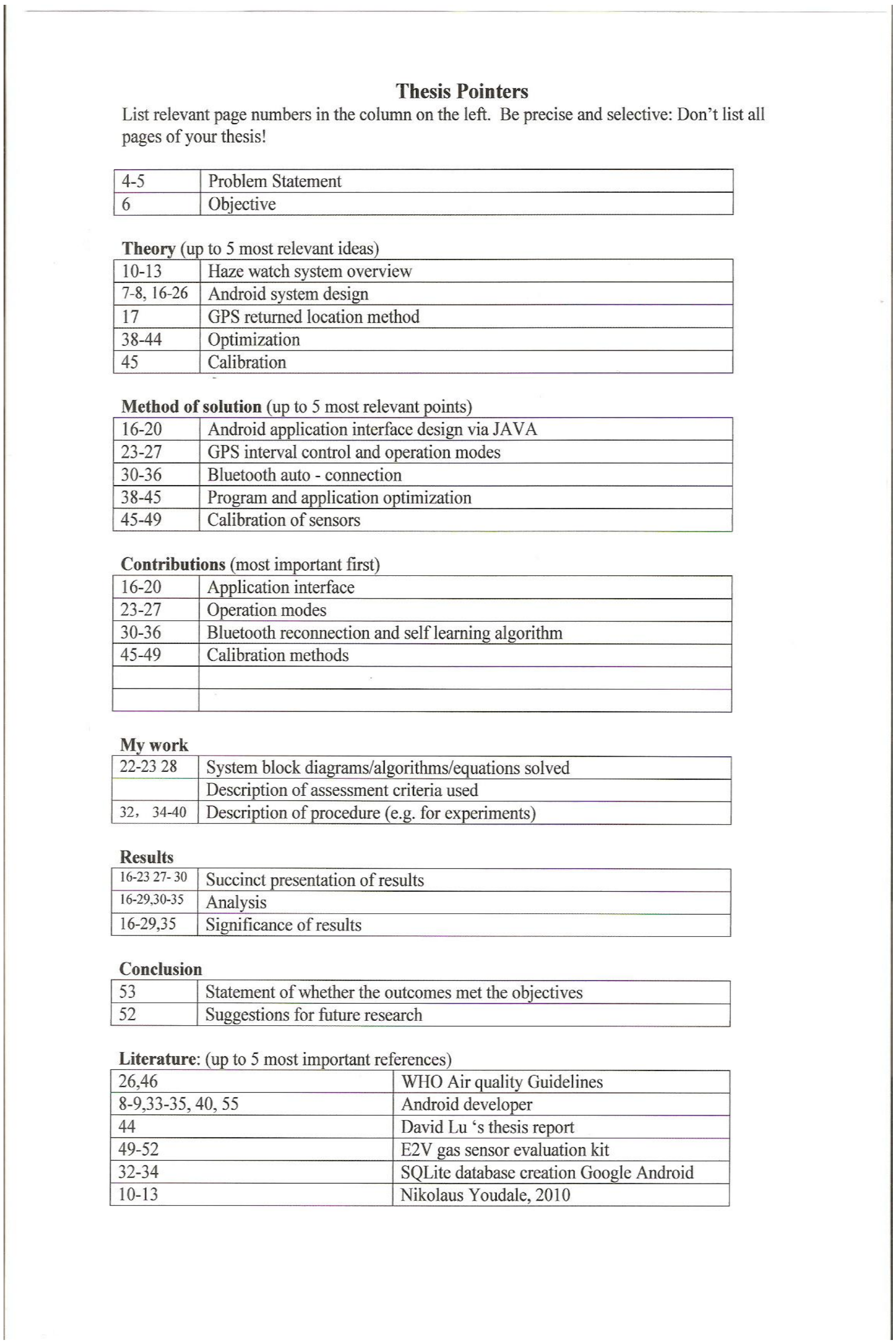
Interface design on android (location, push buttons and so on)
Create more functionalities and introduce new operation modes
Come up Bluetooth reconnection method to deal with signal loss problem
Optimize program in aims of fast speed and low memory cost
Build up a Gas container associated with one calibration method
Debugging and field tests

E. **Suggestions for future work**

Calibration method and results, Bluetooth auto-connection stability and testing,
Sufficient mode operations for user requirement, and privacy concerns.

While I may have benefited from discussion with other people, I certify that this thesis is entirely my own work, except where appropriately documented acknowledgements are included.

Signature: [illegible] Date: 20 / 10 / 2011



Thesis Pointers

List relevant page numbers in the column on the left. Be precise and selective: Don't list all pages of your thesis!

4-5	Problem Statement
6	Objective

Theory (up to 5 most relevant ideas)

10-13	Haze watch system overview
7-8, 16-26	Android system design
17	GPS returned location method
38-44	Optimization
45	Calibration

Method of solution (up to 5 most relevant points)

16-20	Android application interface design via JAVA
23-27	GPS interval control and operation modes
30-36	Bluetooth auto - connection
38-45	Program and application optimization
45-49	Calibration of sensors

Contributions (most important first)

16-20	Application interface
23-27	Operation modes
30-36	Bluetooth reconnection and self learning algorithm
45-49	Calibration methods

My work

22-23 28	System block diagrams/algorithms/equations solved
	Description of assessment criteria used
32， 34-40	Description of procedure (e.g. for experiments)

Results

16-23 27- 30	Succinct presentation of results
16-29,30-35	Analysis
16-29,35	Significance of results

Conclusion

53	Statement of whether the outcomes met the objectives
52	Suggestions for future research

Literature: (up to 5 most important references)

26,46	WHO Air quality Guidelines
8-9,33-35, 40, 55	Android developer
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10-13	Nikolaus Youdale, 2010

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Acknowledgements

I would like to acknowledge the other members of the Haze watch project, Kunxuan Bi, Hailian Zhang and Junjie Jiang for their support and hard work throughout this project. I would also like to specially thank my supervisor, Associated Professor Vijay Sivaraman who provided our group with excellent guidance, direction and support throughout this project.

1. Introduction:

Air pollution is a major environmental risk to health and it is estimated to cause approximately 2 million premature deaths worldwide per year. (World health organization, 2008) Exposure to air pollutants is largely beyond the control of individuals and requires action by public authorities at the national, regional and even international levels.

The quality of the air we breathe directly affects human general health and well being. The regular monitoring and maintenance of air quality is, therefore, extremely important for our overall quality of life. A key environmental issue which Australia currently faces is reversing the degradation of our outside and indoor air quality. Aside from affecting human health, the presence of air pollutants in high levels can also impact upon wildlife and vegetation.

The main cause of a build-up in air is the emission of exhaust fumes from motor vehicles, industries. The quality of air is usually poorest, therefore, in highly urbanised areas. In Australia this is particularly true of larger cities such as Sydney, where fossil fuel emissions from cars contribute to 80 per cent of air pollution. (Skwirk Schooling)

Current systems existing in monitoring air pollution levels are usually established or owned by the government, the most typical formation of those systems are numbers of fixed stations over an entire city. This structure of monitoring air qualities not only exists in Australian but also worldwide. Such sparse monitoring cannot effectively monitor some pollution regions such as heavy industrial pollution areas, tunnels, and inner city. Therefore the estimated level of pollution in these regions will provide the public an unreliable result.

To overcome such issues, the "Haze Watch system" exploits this fact by taking advantage of the built-in GPS hardware found in many such as Smart phones. So that a real-time air quality results will be provide to the public.

1.1 Project objectives

Upon all the current finished work done by previous year in the area of collect, manage and communicate environmental information to the community, which pretty clear leads to our project aim in the area of android interface.

Our aim with interface design should fulfill the below criteria:

- Improve the general display format of the current existing application interface
  - Push buttons, Spinners, Amount of text view information and Checkboxes.
- Create more functionalities inside the application for users to have some control on the app
  - Graphical display of data Readings VS Time or Distance and GPS interval control options
- Fix the current existing problem
  - GPS termination problem
    Back ground location tracking is still activated after the application exists.
  - Data filtering problem
    At sensor warming up stage, readings provided are unreliable so that needs to be filtered out.
- Running the application as a background process

Our role in particular for thesis is in area of:

- ✧ Interface design
- ✧ Implementation and facilitation uploading of readings to the server, via a Smartphone.
- ✧ Achieve Bluetooth auto- connection and detection on Smartphone to device
- ✧ Debugging and testing of application performance
- ✧ Help supervisor with Calibration of sensing unit device sensors

2. Background

Air pollution is one of the most important factors affects the quality of life and health of increasingly urban population of industrial societies. In New South Wales, DECCW (Department of Environment, climate change and water) has responsibility of monitoring air qualities in Sydney, Pictured in Figure 1, they currently have 14 fixed monitoring stations covering entire city of Sydney, there are additional 6 covering the rest of the state.

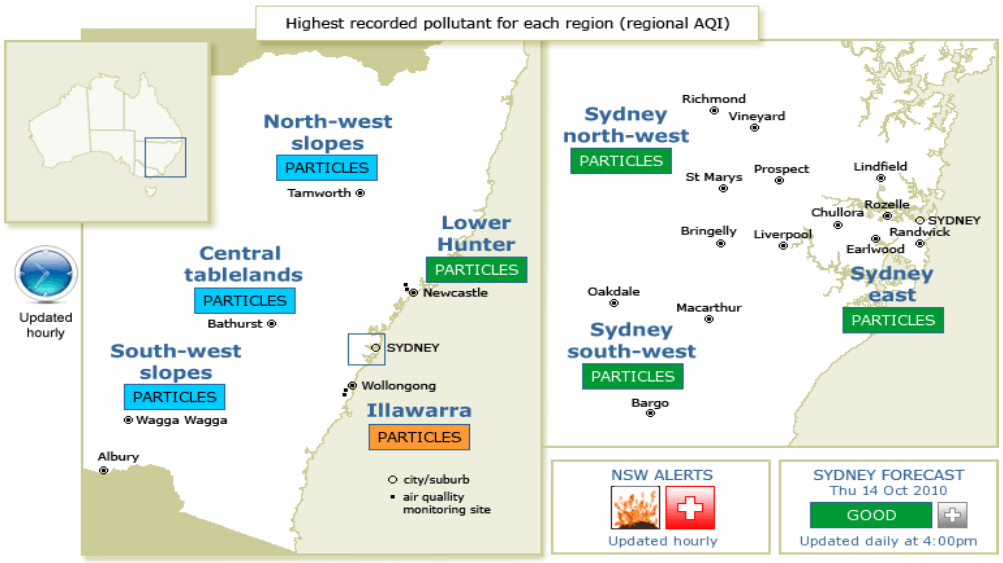


Figure 1 : The DECCW air quality index map

These fixed stations measure pollutant level readings that community can access via a separate page; readings are updated on their WebPages in an hourly basis. DECCW updating readings refer to a world regional air quality index (RAQI), the five pollutants they currently monitor are:

- Ozone(O_3)
- Carbon monoxide(CO)
- Sulfur Dioxide(SO_2)
- Nitrogen dioxide(NO_2)
- Particulate matter (PM)

Apart from Sydney, all major cities have networks of monitoring stations providing continuous measurements of the most important pollutants. However, the number of these stations is usually very small. Furthermore, currently data of the different pollutants measured at different stations in city are aggregated to a single number, the air quality index (AQI), that is published once a day on a website. In other words, there is not enough data gathered to evaluate air quality in a given neighbourhood and the publicly available information is even more deficient.

2.1 Related work--- Android operating system

Android is a software stack for mobile devices that includes an operating system, middleware and key applications. Android's mobile operating system is based on the Linux kernel, be known as the first truly open and integrity mobile system created for the mobile terminal. Google and other members of the Open Handset Alliance which includes HTC, T-mobile, Motorola, Samsung, LG and more than 30 other companies collaborated on Android's development and release. The android is a total open platform which been constructed with open source strategy. Manufacturer and developer can feel free to design and produce the phone consistent with their own needs. For now, the Android operating system is already became the world's best-selling Smartphone platform. [*Wikipedia*]

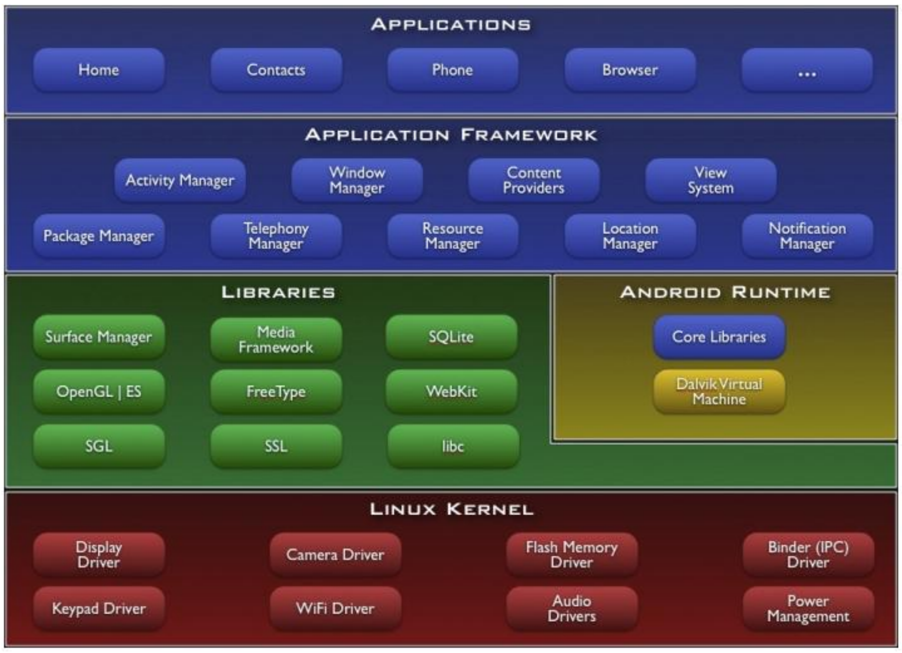


Figure 2: Major components of the Android operating system

The above diagram shows the major components of Android operating system. In the application layer, Android has a set of core applications including web browser, contacts, maps, Email, SMS program and others. All applications are written in Java programming language. The Android SDK tools are used to compile the code along with any data and resource files into an *Android package* with an .apk suffix. All the code in a single .apk file is considered to be one application and is the file that Android devices use to install the application.

Android includes a set of C/C++ libraries, these capabilities are exposed to developers through the android application frame work. Some of the core libraries are shown in Figure 2. Android also includes a set of core libraries that provide most of the functionality available in the core libraries of the Java programming language. Every Android application runs in its own process, with its own instance of the Dalvik [1]virtual machine.

By contrast iOS [2]with Android, iOS does not expose any low level Bluetooth APIs (a requirement), whereas Android does. In most other areas, such as User Interface, location tracking and Internet connectivity, Android interfaces are generally easier to use as well. But more significantly, Android's openness where developers can pretty much create and deploy anything, should make development easier, once developers become acquainted with the system.

The few main features that mainly help our team with interface design are:

- Application frame work
- DVM- virtue machine help with optimization
- Graphics powered by a custom 2D graphics library
- Media support – image audio video support
- SQLite - database
- Bluetooth,3G,WI-FI and GPS

[1] **Dalvik** is the process virtual machine (VM) in Google's Android operating system. Dalvik is thus an integral part of Android, which is typically used on mobile devices such as mobile phones, tablet computers and notebooks. Before execution, Android applications are converted into the compact Dalvik Executable (**.dex**) format, which is designed to be suitable for systems that are constrained in terms of memory and processor speed.

[2] **Apple's mobile operating system**, originally developed for the iPhone, it has since been extended to support other Apple devices such as the iPod touch, iPad and Apple TV.

3. Haze watch system

The haze watch system project shares some common features, and builds on some ideas base on other projects. Some of the existing projects are either too complicated in functionality on each device or too general in away only collecting and visualizing different types of data. The aim of making a haze watch system is trying to only focus as much as possible in air pollution monitoring alone, and utilize as much as existing hardware and communication software products nowadays for the convenience of user needs.

3.1 Overview of the system

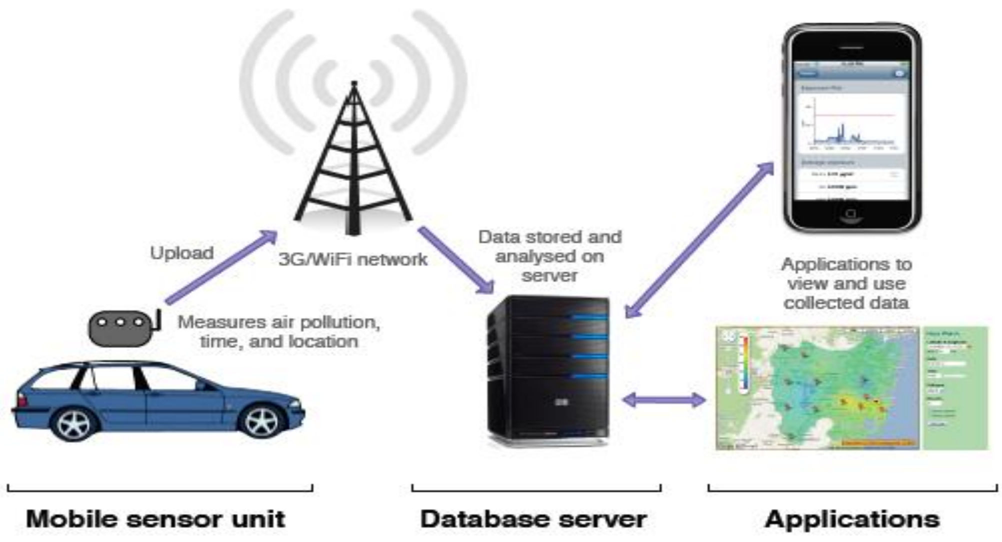

Upload
3G/WiFi network
Data stored and analysed on server
Measures air pollution, time, and location
Applications to view and use collected data
Mobile sensor unit
Database server
Applications

Figure 3: General overview of the Haze Watch System

Haze watch system consists of three essential components illustrated in Figure 3: a mobile sensor unit, ad database server and some client applications, the design aim of this new style measuring air pollutants system is:

- Capable to collect different air pollutant levels
- Manage and analyze pollutant data readings
- Provide air pollution data on request via internet and various applications both visually and as raw data format. (Nic Youdale, 102010)

The general plan of the system is, with the mobility (being attached to a vehicle and otherwise) advantage of the sensor unit itself and the ability to collect pollutant measurements, real-time pollutant measurements will be carried out. Pollutant readings and their corresponding GPS coordinates and time stamps will be uploaded via a 3G/Wi-Fi network to our server. In this case clients can use various applications the system provided, to access and visualise those readings for various purposes. The current two applications that our system can provide to users are an iPhone application showing pollution exposure and a pollution map. (A. Chow. Haze Watch system: Pollution Map, 2010)

3.2 Mobile sensor unit

The mobile sensor unit consists of two major components: a wireless sensor board shows in Figure 4 and an android platform application.

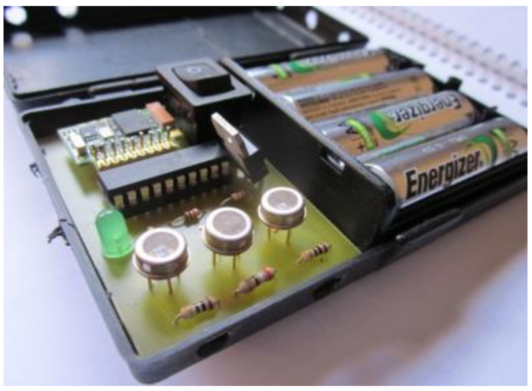


Figure 4: Wireless sensor board and android operating system

The wireless sensor board has three sensors attach to it; the three pollutants we are currently monitoring are Nitrogen dioxide, Ozone and Carbon monoxide. Three gas sensors interface with the microcontroller through an A/D (analogue to digital converter), where voltage outputs will be converted to an 8 bit digital value. These groups of assembled packets of data will send to Smartphone for further processing via a Bluetooth module.

Bluetooth transmission method is selected in the wireless sensor board is because it builds in to most phones, provides reliable transfer of data and has a range of up to 10m . The only potential disadvantage of using Bluetooth over a wired technology such as USB for instance is the power efficiency. All wireless circuits require significant power to transmit data (several mill watts). Therefore most of the power dissipation of the wireless sensor board will mainly related to the microcontroller computation and Bluetooth transmission. The data rates of currently Bluetooth module ARF32 is up to 721kbps which is more than sufficient for the packets size of the wireless sensor board.

The sensor wireless sensor board has been designed and built by James Carrapetta in last year. The device is designed to be as simple and low cost as possible, therefore which leads to utilising existing hardware present on Smartphone.

3.2.1 Message structure

For successfully communicate between the wireless sensor board and the Smartphone a two side agreed message structure should be applied. The current message sent from wireless sensor board contains following information:

- Header indicates start if message (default 0xFFFFFFFF)
- Version of the message (1 byte)
- Device identification number(2 bytes)
- Total number of sensors on the device board(1 byte)
- Calibration equation coefficients(7 bytes)
- Reference voltage for digital to analogue conversion method (2 bytes)
- Number of measurement readings being sent(1 byte)
- Sensor readings(2 bytes)
- Checksum(Error checking)
- Footer indicates end of one message(default 0xEEEEEEEE)

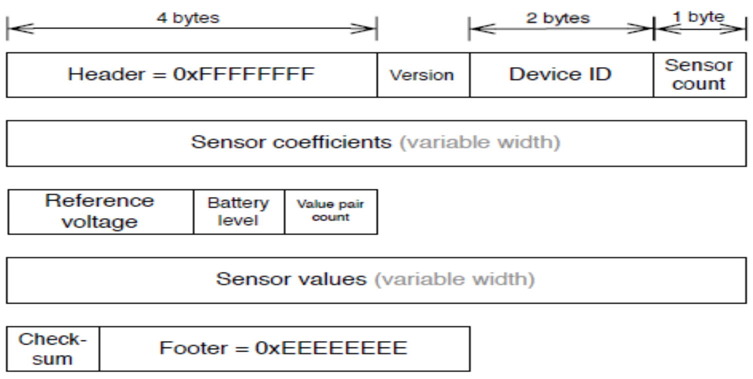


Figure 5: Format of Message (refer to last year thesis report)

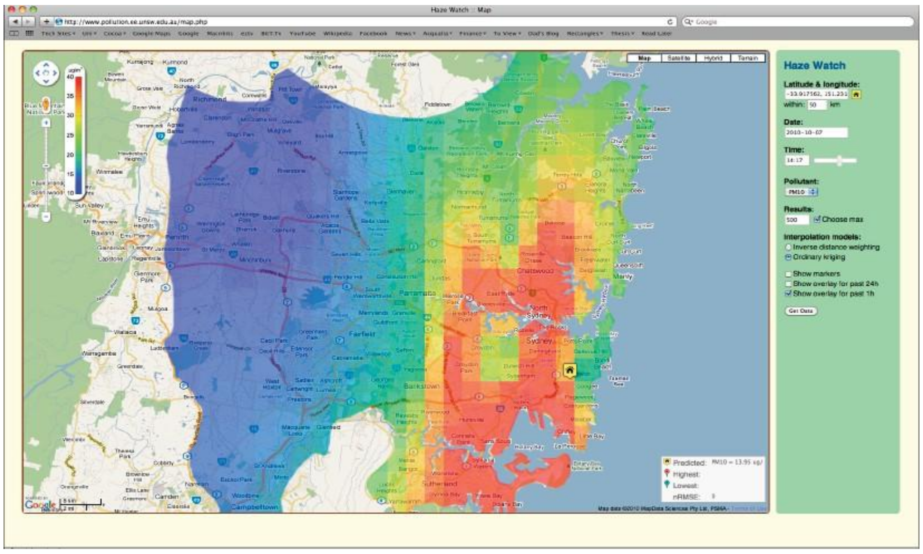
As the device is built to be as simple and low cost as possible, and the mathematical capabilities of the microcontroller PIC16F690 only handle 8-bit integer math in hardware and has no floating – point math hardware. Therefore higher precision math and algorithms will utilise the existing software inside the android platform as it has high level programming language and build in libraries. (James Carrapetta, Oct 2010)

Currently the microcontroller assembles 10 readings for each sensor and sends them all to the Smartphone in a period of 30 seconds per message packet. The Bluetooth connection is established periodically to the Smartphone, and this stream of data will be read and decode then displayed on the screen of the android application.

3.2.2 Client applications

Project webpage: (http://pollution.ee.unsw.edu.au/)

- Includes a pollution map and allows users to view the pollution level in a coloured graphical map shown in below and check a specific point for the detailed information about each pollutant.



Haze Watch

Latitude & longitude: -33.917562, 151.231

within: 50 km

Date: 2010-10-07

Time: 14:17

Pollutant: PM10

Results: 500 ✓ Choose max

Interpolation models:
- Inverse distance weighting
- [✓ Ordinary kriging]

- Show markers
- Show overlay for past 24h
- ✓ Show overlay for past 1h

iPhone exposure application

- Users can track their own location and display it with pollution level data received from server database, It also can compute and draw a graphical chart to display the users exposure to pollutants over time

3.2.3 Previous android application interface

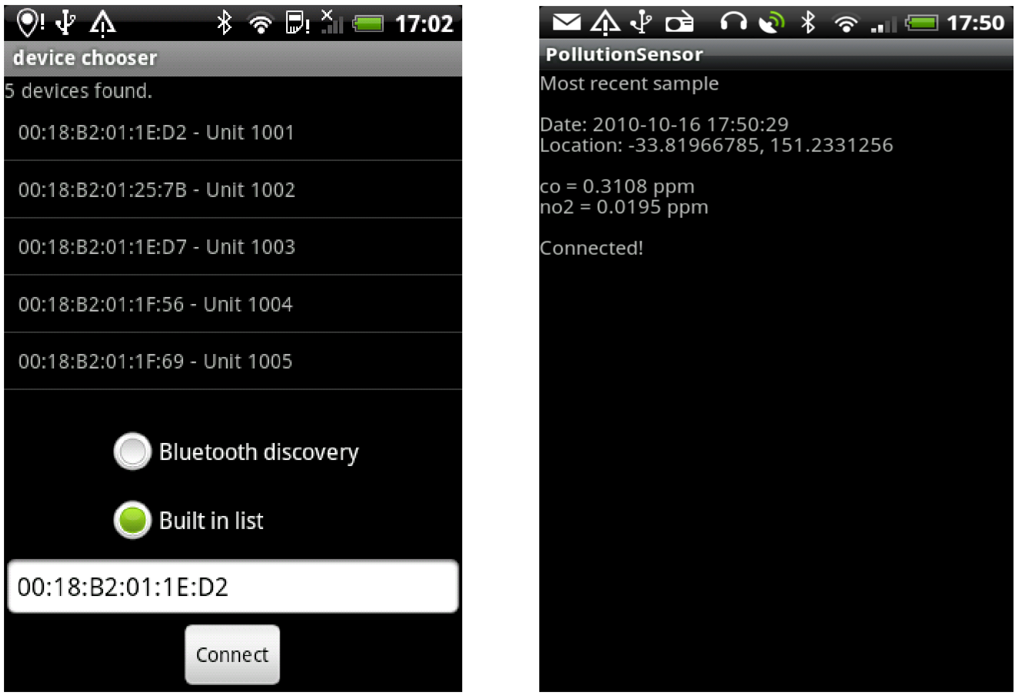
A key part of the overall Haze watch system is an internet connected Smartphone in android platform. Smartphone always has build in GPS sensors as well as network connection hardware, which eliminates difficulties of build one into mobile sensor device.

The requirements for a Smartphone platform can use in the system are:

- Bluetooth support and Internet connection
- Large number of users for the Smartphone
- Good application program interface and support
- Build in GPS for location-based services

The role that a Smartphone plays in the system is a connection bridge between the mobile sensor hardware and database server. The essential functions of the application are:

- Ability to pack sensor readings with their GPS coordinates and time stamp
- Ability to transmit packages of readings to database server


17:02
device chooser
5 devices found.
00:18:B2:01:1E:D2 - Unit 1001
00:18:B2:01:25:7B - Unit 1002
00:18:B2:01:1E:D7 - Unit 1003
00:18:B2:01:1F:56 - Unit 1004
00:18:B2:01:1F:69 - Unit 1005
( ) Bluetooth discovery
(●) Built in list
00:18:B2:01:1E:D2
Connect

17:50
PollutionSensor
Most recent sample

Date: 2010-10-16 17:50:29
Location: -33.81966785, 151.2331256

co = 0.3108 ppm
no2 = 0.0195 ppm

Connected!

Figure 6 Smart phone application connection screen (left) and main screen (right)

Once you launched in to the previous application, a device chooser connection screen will comes out in Figure 6 left. This screen allows the user to select a pollution sensing device to connect to.

The device chooser screen has an area of listed devices in the top; those devices have already built in into the application previously for testing purpose. The screen also includes a field where user can scan for any Bluetooth enabled hardware nearby. The text field at the bottom is for uses manually type in a MAC address of the Bluetooth unit in order for the application to connect to, if the device discovery fails.

The Bluetooth hardware on the android phones allows multiple simultaneous connections, which means the use of this application wont impact the user's ability to use other Bluetooth hardware at the same time. (N.Youdale. Thesis report P41)

The main screen of the application is illustrated in the right of figure 6. It displays status of connection, location, time and pollutant readings. All the readings are stored in memory and later dumped to a file in CSV[3] format. While each sample is being collected, the application itself also packages those readings as XML formats and then uploads to server.

To save battery on both the phone and the sensor hardware, the application does not remain connected to the hardware all the time. Rather, it connects periodically to receive the latest message, before disconnecting, sleeping for a short while, and then reconnecting.

From now on the following chapters will go through all the new features of our implemented interface for the air pollution monitoring system.

[3] The **comma-separated values** (**CSV**) file format is a set of file formats used to store tabular data in which numbers and text are stored in plain textual form that can be read in a text editor.

4. New Android mobile application interface

It is not hard to recognise the difference between our new created interface shown in figure 6 and the previous version. With all the past text viewed information retained we also include information fields (from top to bottom in figure 6):

- Connected Sensor board ID.
- Address information. (**Session 4.2)**
- Pollutant Bush buttons (**Session 4.3**) and corresponding readings.
- Battery status of the sensor board. (**session 4.4**)
- A graphic plot of real time taken pollutant data.(**Session 4.5**)
- User travel Trip time.
- Number of samples being recorded.
- GPS interval. (**Session 4.6**)

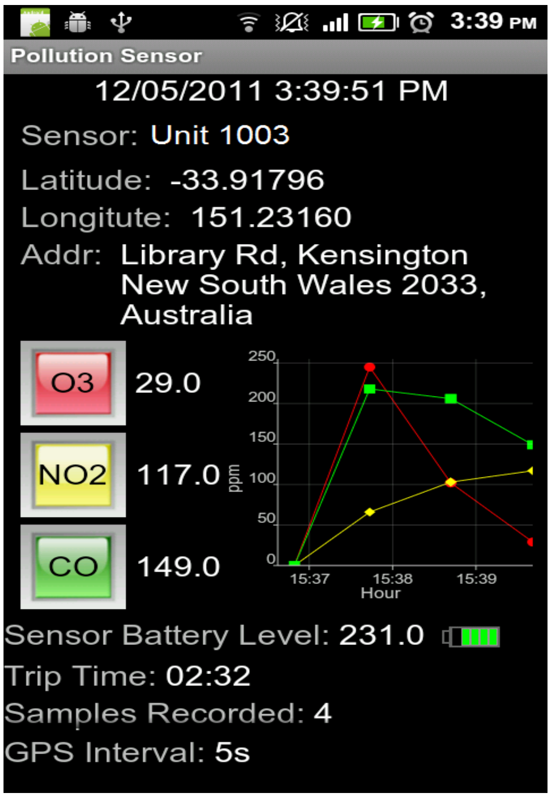

Pollution Sensor
12/05/2011 3:39:51 PM
Sensor: Unit 1003
Latitude: -33.91796
Longitude: 151.23160
Addr: Library Rd, Kensington New South Wales 2033, Australia
O3 29.0
NO2 117.0
CO 149.0
Sensor Battery Level: 231.0
Trip Time: 02:32
Samples Recorded: 4
GPS Interval: 5s

Figure 6: New interface overall view

4.1 Warming up message screen

The warming up screen is introduced here is due the performance of the sensors on the sensor board, those sensors requires certain amount of time to warm up before taking measurements which means readings taken at warming up period of sensors makes no contribution to our pollution monitoring system.

Filtering those data process is performed inside the application program. Once the application detects the obtained message illustrates the sensor is warming up. The bellowed screen-shot in Figure7 will shows up to users.

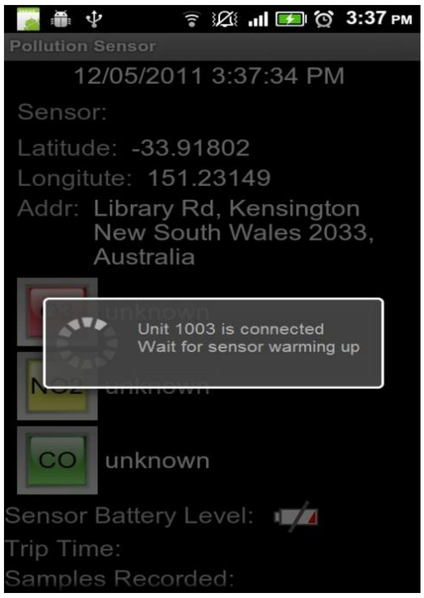

Pollution Sensor
12/05/2011 3:37:34 PM
Sensor:
Latitude: -33.91802
Longitute: 151.23149
Addr: Library Rd, Kensington New South Wales 2033, Australia
unknown
unknown
CO unknown
Unit 1003 is connected
Wait for sensor warming up
Sensor Battery Level:
Trip Time:
Samples Recorded:

Figure 7: Warming up screen whilst sensors in hardware is warming up

The way we achieve warm up message detection is by modify the sensor readings inside the overall message protocol (detailed protocol in session 3.2.1). simply assigning all negative hex values in sensor values inside the protocol, during the digestion of the application with the message**,** once the program detects all the sensor readings a coincidently the same negative values, the warming up page will be displayed.

4.2 Current location Estimation

Recall the previous interface only displayed the location information in logitude and latitude, which is certainly accurate but not in hunman sense. We decide to include a field in display which could show to user the street name ,suburb and other detailed infomation about location. (See figure 6 for location display)

The way we obtaining positioning information is by using combined response of civil GPS,Differential GPS,and assisted GPS service inside the Android platform. The reason we using combined respose is due to it allows the strength of one to compensate for the weakness of another to provide a more reliable and robust location solution.

Civil GPS is the most basic positioning topology, but due to its relatively service positioning accuracy is not very high and the error estimation can be up to 200m maximum, these error will affect the location seriously, user may see a wrong location information being displayed in the interface.

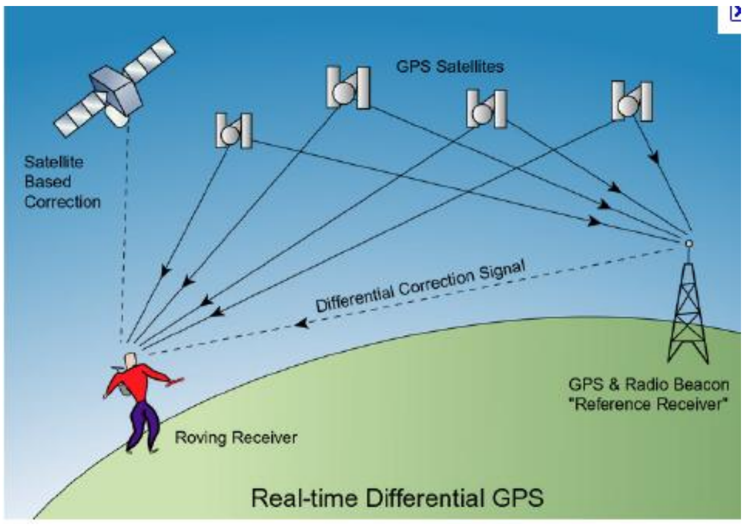

GPS Satellites
Satellite Based Correction
Differential Correction Signal
GPS & Radio Beacon "Reference Receiver"
Roving Receiver
Real-time Differential GPS

Figure 8 Differential GPS

With the help of a differential GPS which not only calculating positions depend on satellites but also taking account the base station response (refer to Figure 8 the reference receiver). Since we know the position of the satellite and the position of the known receiver, we can take the difference between the real range and the pseudo range to create a correction. We can then apply the pseudo range correction for each satellite to the unknown or rover receiver to calculate a better position. So by using the same techniques to apply differential corrections to the ranges we can hope for a 30 centimeter-3 meter solution. (Greg Pendleton, 16th July 2002)

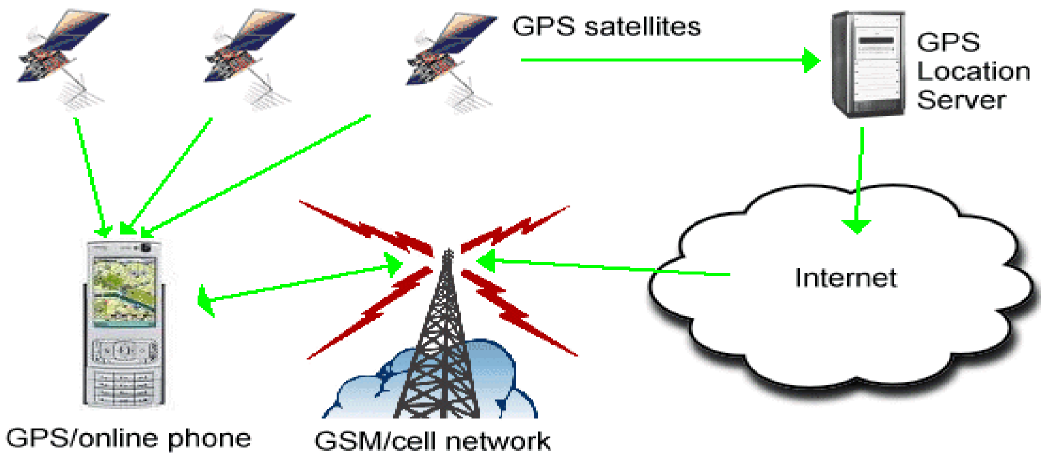
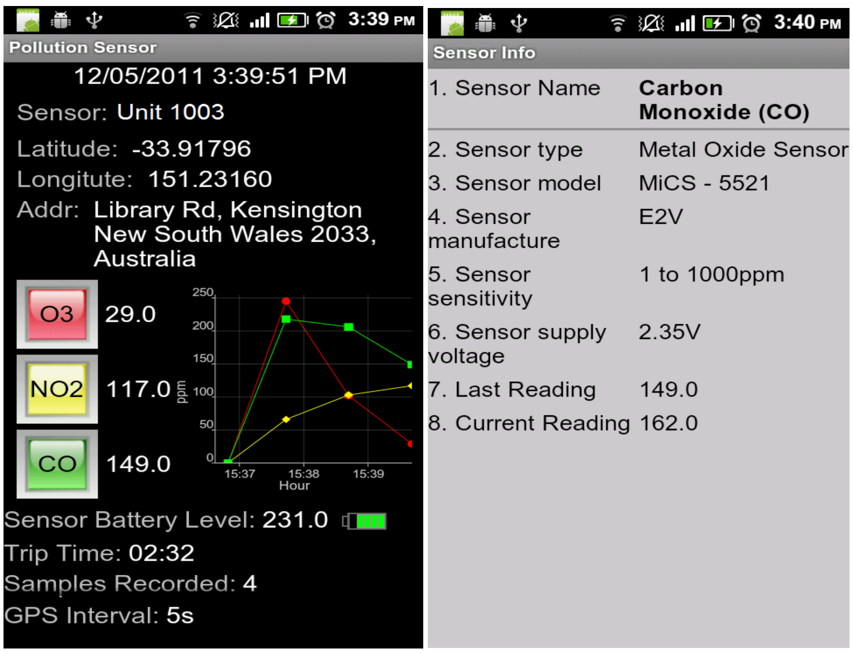


Figure 9 Assisted GPS

The main advantage of Assisted GPS (AGPS) for the application is that it will allow the Smartphone's GPS to operate in weaker signal conditions and determine positioning quicker than most standalone GPS receivers. AGPS also helps to save battery power by handing off some computational duties to an assistance server.(Steve Litchfield, 25th June 2007)

Once longitude and latitude being confirmed, the program itself will forward this two data to Google map server, applying the inverse estimation using build in "Geopoint" function that Google Map provides, and also under the refreshment of "locationlistener" function updates new longitude and latitude values to Google map server inside Android, we make an individual display system for the Location function, So that users can observe a real time location change and also the server will obtain the most reliable location information.

4.3 Push buttons and contents


3:39 PM

Pollution Sensor

12/05/2011 3:39:51 PM

Sensor: Unit 1003

Latitude: -33.91796

Longitute: 151.23160

Addr: Library Rd, Kensington
New South Wales 2033,
Australia

O3 29.0

NO2 117.0

CO 149.0

Sensor Battery Level: 231.0

Trip Time: 02:32

Samples Recorded: 4

GPS Interval: 5s

3:40 PM

Sensor Info

1. Sensor Name	**Carbon Monoxide (CO)**
2. Sensor type	Metal Oxide Sensor
3. Sensor model	MiCS - 5521
4. Sensor manufacture	E2V
5. Sensor sensitivity	1 to 1000ppm
6. Sensor supply voltage	2.35V
7. Last Reading	149.0
8. Current Reading	162.0

Figure 10 Push buttons and sensor information screenshot

Considering users may wonder what type of sensor is being used in the sensing device and its performance, but due to limitation of amount of information can be displayed inside one screen we include push buttons for user to check detailed sensor datasheets information.

Apart from what is being displayed currently, we will add the last calibration date and duration consist in sensor information page. The reason calibration is a very important data needs to be display is the low-cost sensors we are using each have a slightly different performance characteristic, meaning that the conversion equation will vary slightly in each sensor unit after a long time functioning.

4.4 Battery status of the “Sensor board”

The aim of display the battery status information of the sensor board hardware on the Smartphone is for the convenience of user. In this way a total transparent of the sensing device can achieve. Recall previously the battery status indication method was only achieved on the sensor device itself by interface microcontroller with a LED. A solid red LED flashing will warn user that batteries will run out.

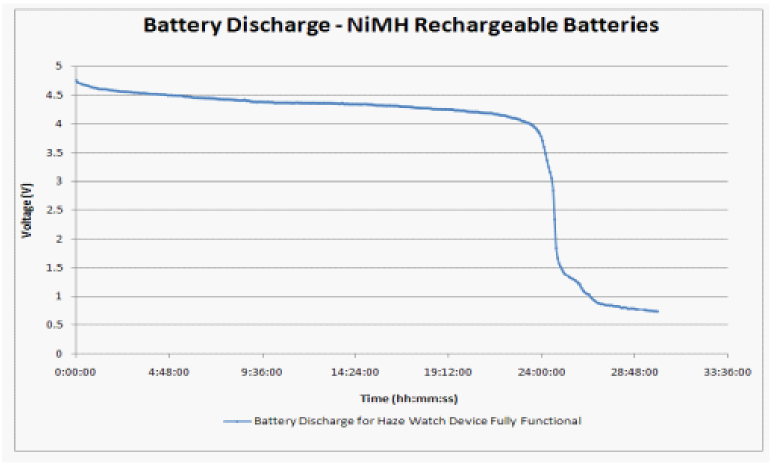


Figure 11: Battery Discharge curve

Figure 12 is a battery discharge curve done by James Carrapetta last year; he kept the sensor device running all day and using MATLAB to import battery condition readings and made this plot. From the graph we can easily recognize that the voltage of the battery slowly drops off during the first 22 hours of operation. During this period the wireless sensor board was completely functional. Similar to all battery discharge curves there is a sudden exponential drop in supply voltage at a critical point. As can be seen in the above graph, the supply voltage dropped off suddenly at approximately 23 hours of operation and during this time, the Bluetooth stopped functioning and the wireless sensor board was inoperable.

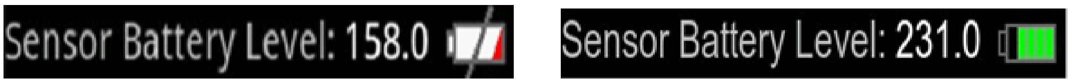


Figure 12: Battery status widget

The way of displaying battery level is shown in Figure 11, according to the battery discharge curve described previously, we created a 5 grids battery icon. The first 4 grids in Green stand for 80% of battery remaining, sensing device functions normally. If only one grid shows in red. It is a reminder for user that battery should be changed.

The value currently displayed for the battery level is in hex representation, Later on the display will be in percentage.

Questioning how we achieved display battery status onto the application, we should look back to overall message structure in session 3.2.1. We include a 1 byte field called “battery_status” in between device ID and sensor count inside message protocol, therefore the battery status will be send to the application all the time
The voltage level of the battery is converted to hexadecimal 0 to 255 values with the process of A/D conversion of a microcontroller. By applying the reverse algorithm we may get the correct voltage of the current battery.
I.e.

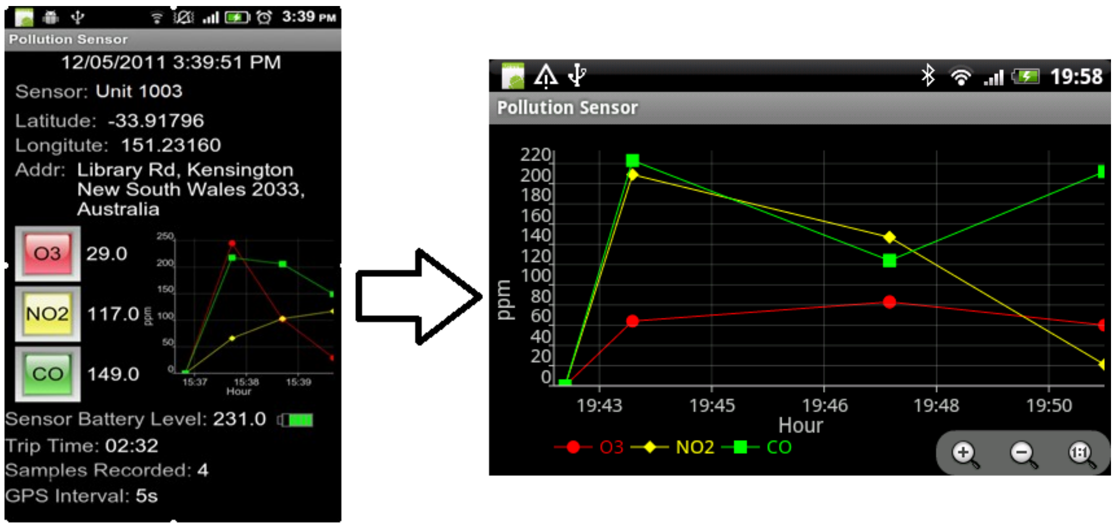
$$\left(\frac{reference\ voltage}{255}\right) * \ (Current\ HEX) = \ Battery\ Voltage$$

$$\text{Reference voltage} = 3.3\text{V}$$

4.5 Real-time graphic plot

“A picture is worth a thousand words.” This is certain true when you are presenting and explaining data. A Graph can help people understand data quickly. Whether you want to make a comparison, show a relationship, or highlight a trend, it helps audience “see” what you are talking about. (Dave paradi, 2005)

Line graphs are being chosen for the purpose of showing pollutant trends, as one of the most common graphical ways, simply use a line to connect the data points. It is useful for showing trends, and for identifying whether two variables relate to one another.


3:39 PM

Pollution Sensor

12/05/2011 3:39:51 PM

Sensor: Unit 1003

Latitude: -33.91796

Longitute: 151.23160

Addr: Library Rd, Kensington New South Wales 2033, Australia

O3 29.0

NO2 117.0

CO 149.0

Sensor Battery Level: 231.0

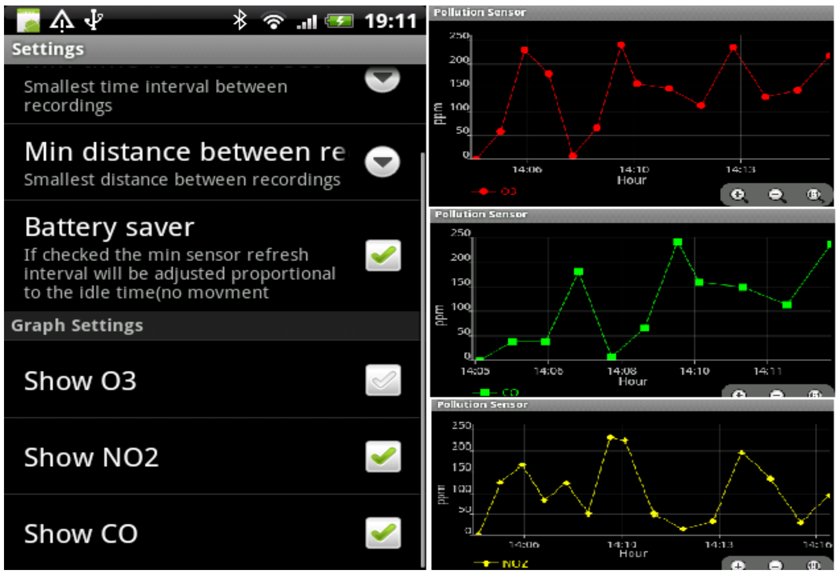
Trip Time: 02:32

Samples Recorded: 4

GPS Interval: 5s

Figure 13 screenshot of graphic display of pollutant readings

The graph can be displayed in full screen size; rotation of the Smartphone will display the graph either in portrait or landscape orientation. Different pollutant readings are indicated in different colours as you may see from Figure 14.


19:11

Settings

Smallest time interval between recordings

Min distance between re
Smallest distance between recordings

Battery saver
If checked the min sensor refresh interval will be adjusted proportional to the idle time(no movment ✓

Graph Settings

Show O3 ☐

Show NO2 ✓

Show CO ✓

Figure 14 graph display settings and its corresponding display

One more feature is that there are three check boxes under settings of the line graph; the aim of this feature is showing each plot only. It is obviously this setting is for the users' convenience of visualising the trend of each pollutant separately and the ability to display one at a time is a most common feature that a normal graphic plot should support.

4.6 GPS interval control

The meaning of GPS interval control means two things:

- Control interval for plotting readings in the graph
- Control upload package rate to server

4.6.1 Mode operation algorithm

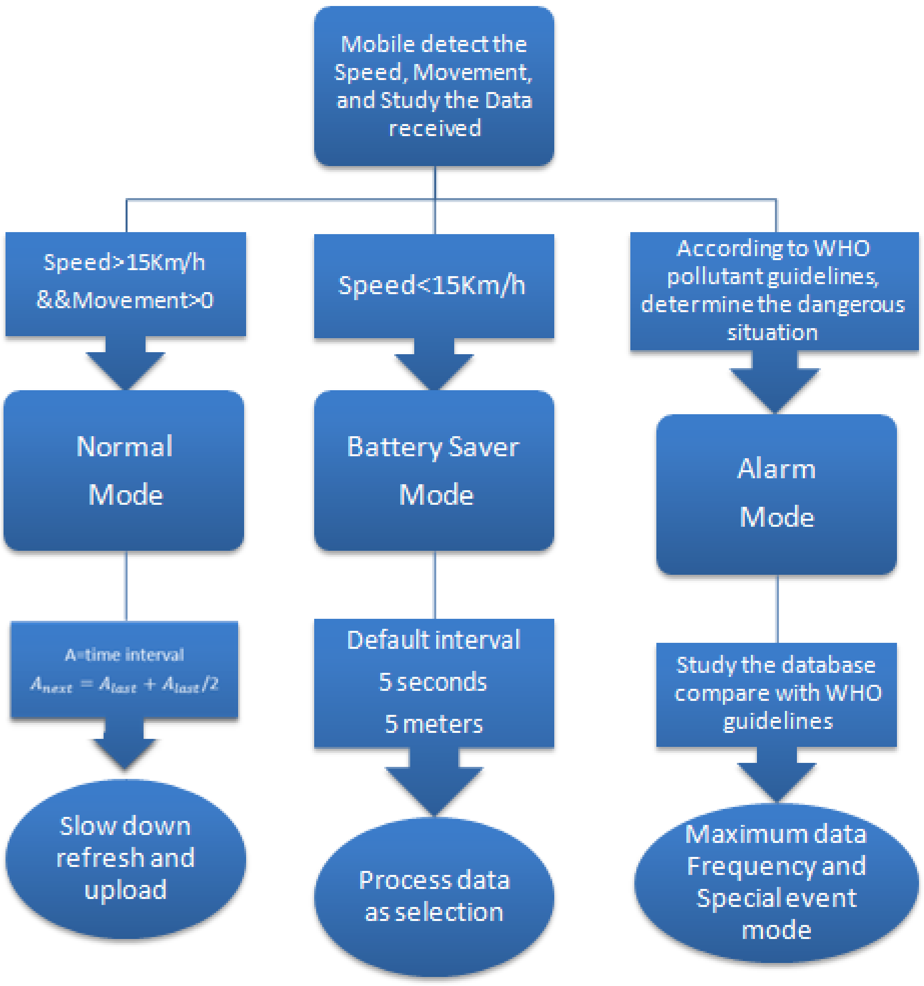

Mobile detect the Speed, Movement, and Study the Data received
Speed>15Km/h &&Movement>0
Speed<15Km/h
According to WHO pollutant guidelines, determine the dangerous situation
Normal Mode
Battery Saver Mode
Alarm Mode
A=time interval $A_{next} = A_{last} + A_{last}/2$
Default interval 5 seconds 5 meters
Study the database compare with WHO guidelines
Slow down refresh and upload
Process data as selection
Maximum data Frequency and Special event mode

Figure 15 Flow chat of algorithm of mode operations

There are three modes will be introduced in this session, the overall algorithm of performing mode operation is showing in Figure 17.

The overall algorithm behind this mode operation is simply doing speed detection of the Smartphone. The speed calculation we implied in our program is a comparison between Haversine formula [4]and GPS returned speed value.

Method 1: Haver Sine formula for obtaining speed:

For any two points on a sphere we can apply this formula to obtain the distance between two points according to given latitude and longitude:

$$\operatorname{haversin}\left(\frac{d}{R}\right) = \operatorname{haversin}(\varphi_2 - \varphi_1) + \cos(\varphi_1)\cos(\varphi_2)\operatorname{haversin}(\Delta\lambda).$$

Where

- Haversin is the haversine function, haversin(θ) = $\sin^2(\theta /2)$ = $(1-\cos(\theta))/2$.
- *d* is the distance between the two points (along a great circle of the sphere).
- *R* is the radius of the sphere 6356.78 km.
- $\Phi 1$ is the latitude of point 1.
- $\Phi 2$ is the latitude of point 2.
- $\Delta\ \lambda$ is the longitude separation.

After obtaining distance between two locations, and travelling time is a known value we can use: $Speed\ (V) = \frac{total\ Travel\ ddistance}{total\ travel\ time}$ formula to obtain the desired speed value. (Wikipedia, 2011)

Method 2: GPS returned speed

Android build in function for GPS not only returns location information of longitude and latitude but also returns speed of motion.

[4] The **haversine formula** is an equation important in navigation, giving great-circle distances between two points on a sphere from their longitudes and latitudes. It is a special case of a more general formula in spherical trigonometry, the law of haver sines, relating the sides and angles of spherical "triangles".

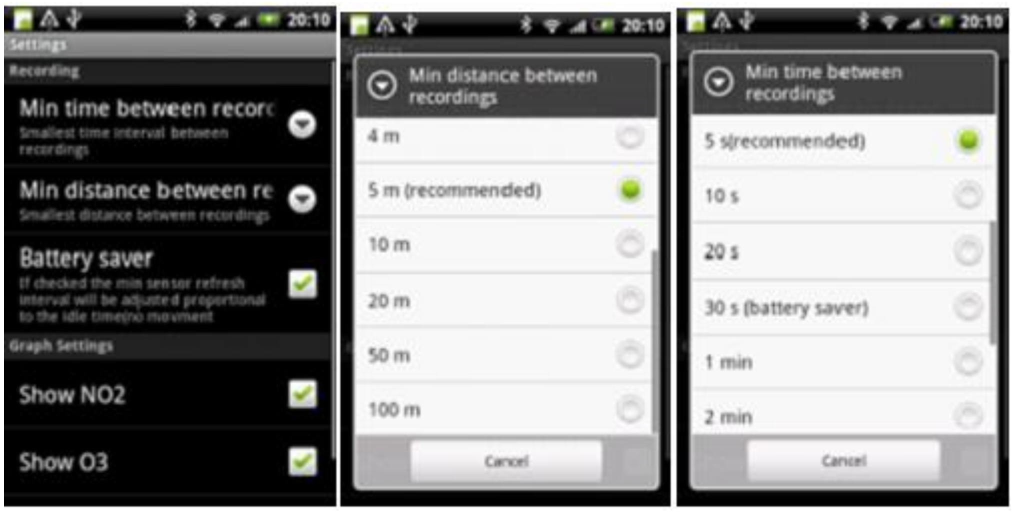
The reason we doing double check in speed, is to verify our algorithm, while we testing the two result of the speed in both method there is almost no difference.

4.6.2 Battery saver mode

If the speed detection results are less than 15km/h, the battery saver mode will automatically activated.

In this mode, application still acquires data from sensing device as usual, and all data will record inside android database, but instead of making plots too frequently, the rate of showing readings on the graph will drop, if battery saver mode is operating for a very long time, the next interval of showing one reading = current interval + current interval /2, this interval changes will keep changing until speed detection jumps to another operation mode.

4.6.3 Normal mode


Settings
Recording
Min time between recorc
Smallest time interval between recordings
Min distance between re
Smallest distance between recordings
Battery saver ✓
If checked the min sensor refresh interval will be adjusted proportional to the idle time(no movment
Graph Settings
Show NO2 ✓
Show O3 ✓

Min distance between recordings
- 4 m
- 5 m (recommended) ●
- 10 m
- 20 m
- 50 m
- 100 m

Cancel

Min time between recordings
- 5 s(recommended) ●
- 10 s
- 20 s
- 30 s (battery saver)
- 1 min
- 2 min

Cancel

Figure 16 Normal mode interval control settings

Normal mode basically allows user control time and distance interval. The same effect as mentioned in the start of this session, the graphic plot interval and rate of uploading package to server will change as a result of making interval choices.

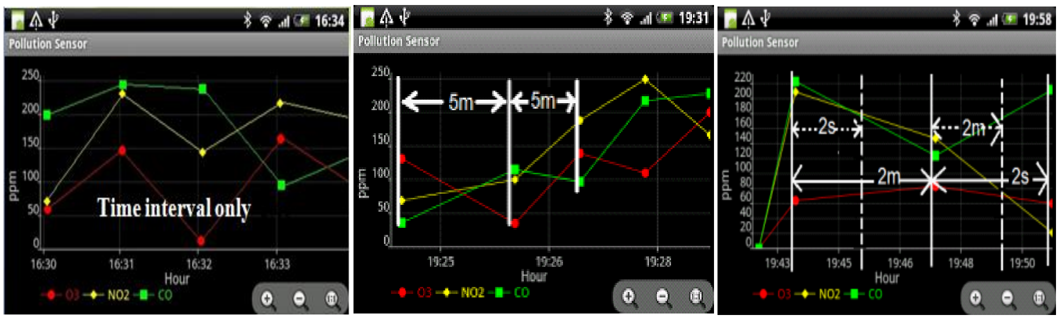


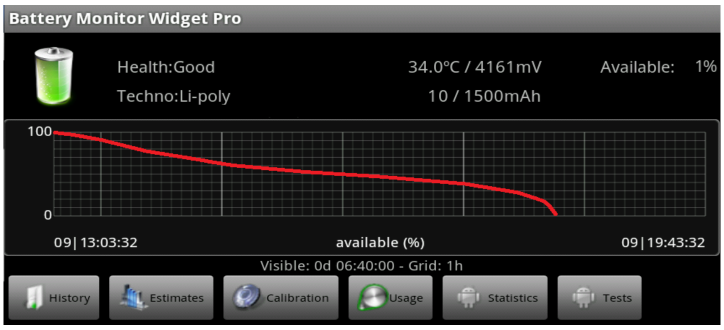
Figure 17 Three different interval option plot figure

Along the options user made in control the interval for time and distance. The line graph will show differently refer to Figure 18. Time interval and distance only means readings and distance basis only. By setting both time and distance; data will displayed in the graph while both of the conditions satisfied see the right picture in Figure 19.

4.6.4 Alarm mode

Alarm mode activation does not depend on speed detection inside the overall operating algorithm. This mode will only activate if the application program detects extremely abnormal pollutant readings. application will first compare the next incoming data and make a comparison between the previous one, to make sure that it is not a system error , then make decision on whether alarm mode should be activate or not.

Once the alarm mode is activated; plot of readings will be displayed and uploaded at a maximum rate, as in this situation users are more willing to collect those pollutant for various purposes.


Battery Monitor Widget Pro

Health:Good 34.0°C / 4161mV Available: 1%

Techno:Li-poly 10 / 1500mAh

Figure 18 Battery saver mode power consumption

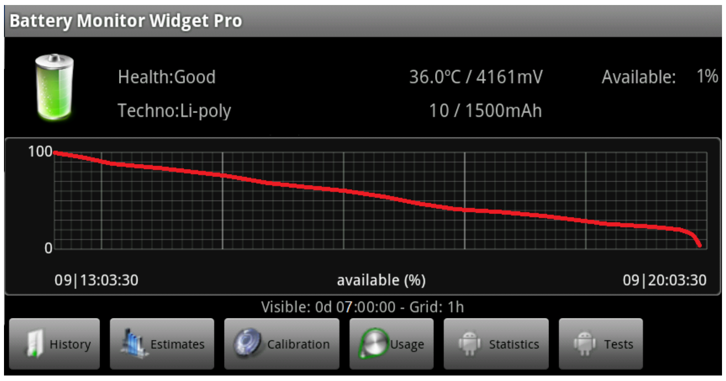
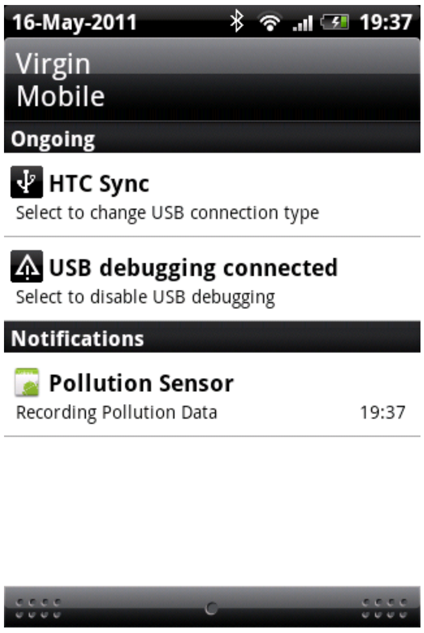


Figure 19 Normal mode power consumption

Figure 20 and 21 are the comparison of power consumption between two mode operations. This tests was carried out at same situation and time while one phone operates in normal mode, another phone operates in battery saver mode. As you may realise that longer supporting time and battery life for battery saver mode, in this mode application lasts for about 7 hours.

4.7 Application background process



16-May-2011 19:37

Virgin Mobile

Ongoing

HTC Sync
Select to change USB connection type

USB debugging connected
Select to disable USB debugging

Notifications

Pollution Sensor
Recording Pollution Data 19:37

Figure 20 background process shows on android

As we mentioned before, the aim that we developed this application is think everything that a user want, to make simple utility software but do great performance that satisfying all users, therefore a simple click that can leads the application to a background process is very important.

Android system provide a "service" mechanism to implement the NUI(Non-User Interface) service, which make the application can process in the background, when background process starts, It will only occupy limited system resources with achieved logic until UI(user interface) requests communication. Its life cycle can last as long as the system memory remains. Background process is a stable function as user expected.

5. Power consumption

Due to Bluetooth, Mobile network and GPS connection always turns on once the application being launched, which leads us to concern about power dissipation of the Smartphone in a case of android phone's battery will drain faster than usual.

On the user side they may feel unsatisfied while running the application.

The power consuming problem inside the application is according to four main factors in the android application:

- Bluetooth connection between device and phone.
- GPS communication power consumption of phone.
- Frequently refreshing displayed data in the graph of the application.
- Uploading package via 3G/Wi-Fi network to server.

As sensor board device sent one set of data per 5seconds to the Smartphone, we need the Bluetooth communication between phone and device all the time along the whole trip of gathering measurements. It’s the same reason for GPS communication as well, because of the location’s accuracy is a very important factor of our application, we want the exactly location all the time, which means we need to get the GPS communication keep on tracking for every slight user movement.

We create a function that under some certain conditions user can actually control the rate of display data on the graph as well the package forwarding rate to server. A slower rate on both sides can save the android phone’s battery, decrease the system memory and 3G/WI-Fi network usage.

6. Bluetooth auto-connection

Sensing unit consists of a Smart phone and a device. Under some conditions the device may turn off or users may take the phone away from the device, but phone application is still running, due to connection lost, Bluetooth scanning will periodically establish to connect device, No matter application is running in background process or battery saver mode, battery will drop or even run out. As a designer we don’t want it to happen. Some algorithms and detection method need to carry out to perfect the application.

The major task that we need to focus on in this section is establishing Bluetooth auto searching and connecting for Smartphone. The reasons that come up with doing this self-learning process is:

- Save power. The Smartphone will end up with infinite loop of searching device after connection lost. No matter what operation mode the application is running on, battery will drop fast and run out soon.
- Customer satisfaction. Users always expect some basic functionality in an application, the self-learning process of Bluetooth will meet customers’ low level expectations. We should always put users at the centre of what we want to achieve.

Introduce a Bluetooth self-learning auto connection process is necessary at this stage; it perfects the application performance as well as satisfied users’ requirement as a fundamental feature.

6.1 Basic Algorithm behind Bluetooth auto-connection

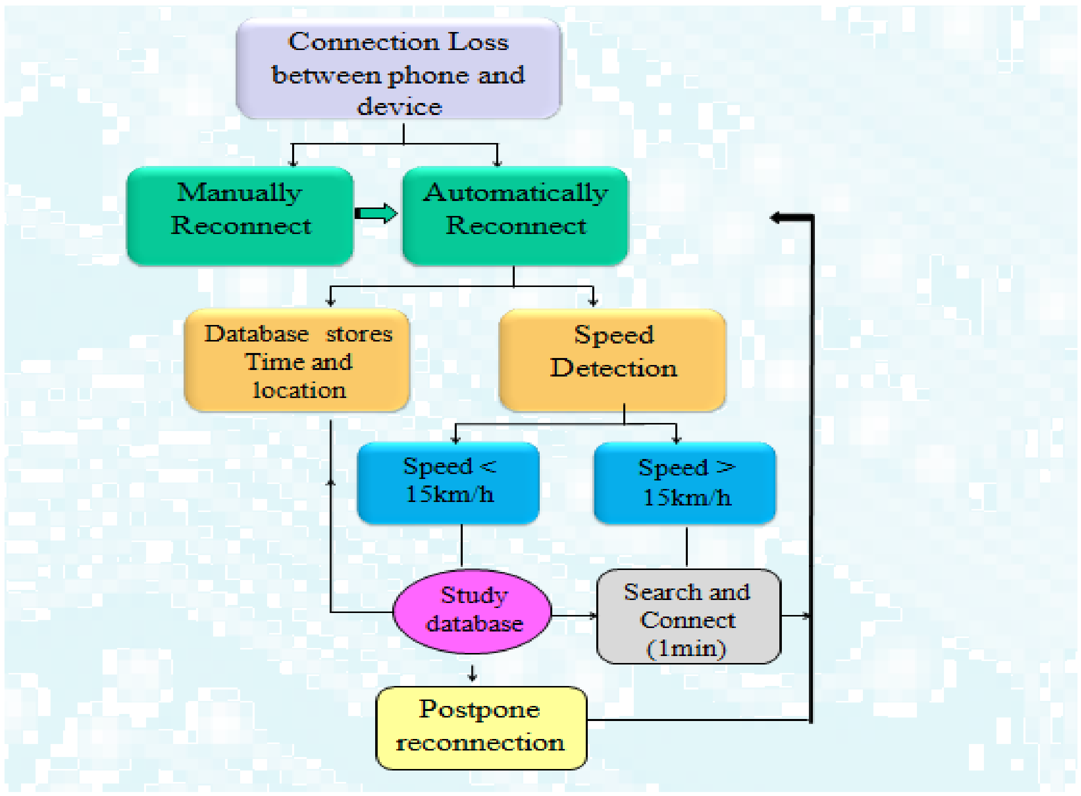


Figure 21 Bluetooth auto-connection algorithm flow chart

The algorithm comes up with a database is that there will be some identical locations and times in a user's daily life that Smartphone will be taken away from device, data base are used here to store those locations and stop application connecting device always. A database is a main component in this self-learning auto-connection program.

From Figure 23, when connection loss detected between Smartphone and device, a selection of manually (Connect Now) or automatically (Dismiss) reconnection screen will pop up waits users' response, manually means application should immediately connect the device using the same unique identifier that successful connection established before; automatically reconnect stats when user do not give any instructions for this notice window about more than a minute. No matters automatically or manually connect; the current location will be written into Database and stored inside for a period of time. If this location often shows up in Database (Normally more than 5 times) within 7days it will be set to as a "hot point", postpone connection (20 minutes) will occur before direct attempt to connect device.

Database has the ability to store and overwrite locations and time; usually locations will be existed in database for a week time, once this location being regards as a "hot point" it will be there for a month. Speed detection is always a preliminary work in this algorithm before choosing postpones or direct connects; it is also a wake up signal for not need to postpone the reconnection anymore. 15km/h is a reference point in speed detection algorithm; as this is a normal person's fast running speed. When during postpone connection situation, once moving speed exceeds 15km/h, Smartphone will start to connect not postpone anymore. Every time when connection does not establish successfully, the overall program will loop back to speed detection until connects to device.

6.2 Android Data storage

Data storage is one of the core functions and fundamental components in application development; Android provides several options for developers to save persistent application data; whether or not you want to export your application's data to others, you need a way to store it. Android provides the following four mechanisms for storing and retrieving data: Preferences, Files, Databases, and Network.

- Shared preferences: this is a general framework that allows developer to save and retrieve key-value pairs of primitive data types; such as Booleans, floats, ints, longs and strings. (Android Developers,2011)
- Files: this method stores files directly on the mobile device or on a removable storage medium. By default, other applications cannot access these files.
- Database: android API contains support for creating and using SQLite databases. Each database is private to the application that creates it.
- Network: developer can also use network (when it's available) to store and retrieve data on your own web-based services.

Shared preference data storage mechanism mainly focuses on storing system configuration information, such as default greeting or a text front to be loaded whenever the application is started. Preference data storage cannot be shared across applications. Network storage has a limitation of application must within 3G or Wi-Fi support area; Files only record and store the data via the format of files, rather creating file database other ways would be better, it seems that those kind of mechanism is not quite suitable for our application.

Android provides full support for SQLite databases. As part of its support for the SQLite database system, Android exposes database management functions that let you store complex collections of data wrapped into useful objects.（Linuxtopia, 2011）For example, Android defines a data type for contact information; it consists of many fields including a first and last name (strings), an address and phone numbers (also strings), a photo (bitmap image), and much other information describing a person. Any databases user creates will be accessible by name to any class in the application, but not outside the application. We may easily realise that creating a SQLite database would be the best option in early age developing of Android phone application.

6.3 Distinctive features of SQLite

Zero-configuration: SQLite does not need to be "installed" before it is used; there is no "setup" procedure.

Server less: most SQL databases are implemented as a separate server process. Programs that want to access the database with the server using some kind of inter-process communication (typically TCP) to send requests to the server and to receive back results. SQLite does not work this way, the process that wants to access the database reads and writes directly from the database files on disk. There is no intermediary server process.

Compact: SQLite is a compact library. With all features enabled, the library size can be less than 350KiB, depending on the target platform and compiler optimization settings. Unneeded features can be disabled at compile-time to further reduce the size of the library. SQLite generally runs faster the more memory you give it. Nevertheless, performance is usually quite good even in low-memory environments.

Variety storage data type: SQLite relaxes the restriction that a particular data type is only allowed to be stored in a column; SQLite allows the user to store any value of any data type into any column regardless of the declared type of that column.

SQLite provides a number of enhancements that are not normally found in other database engines. It is simple to administer, operate, embed in a large program and maintain and customize. (SQLite, 2011) Android default Database engine is SQLite. SQLite is a lightweight transactional database engine that occupies a small amount of disk storage and memory, so it's a perfect choice for creating databases on many mobile operating systems such as Android, iOS. Based on those excellent qualities, we find that it is the most suitable database that should be associated with our pollution application.

6.4 SQLite Implementation on Android system

SQLite on Android does not have a management interface or an application to create and manage databases from, so we're going to create the database ourselves by code. First, we will create a class that handles all the operations required to deal with the database such as creating the database, creating tables, inserting and deleting records and so on.

SQLiteOpenHelper: is a helper class in to manage database creation and version. This class provides two methods to override to deal with the database:

- onCreate: which when database is created, it helps to create tables and columns to associated stored information.
- onUpgrader: invoke when we make modifications to database such as altering, dropping, creating new tables.

Time	Latitude	Longitude	Connect or not
69576354213	13.98765	139.78365	1
78521358930	15.15486	180.26346	0

Table 1 an Example of stored data in database

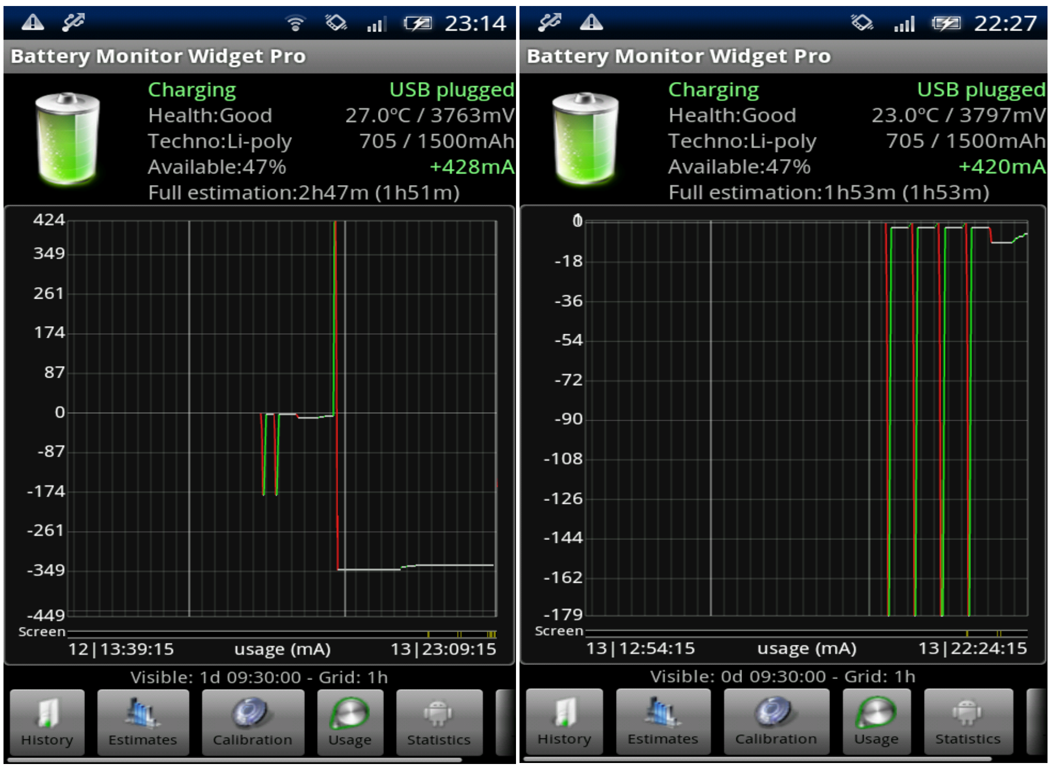
The members that contains in our database class are current time, location in latitude, longitude, and connection status (1 for established; 0 for not).

The structure of "SQLiteOpenHelper" needs Context con, database name, "CursorFactory" (normally is null, can be used to implement some extra validations or operations), and version schema of the database. We also use Content Providers for gaining location longitude and latitude values; But all content providers implement a common interface for querying the provider and returning results — as well as for adding, altering, and deleting data. It's an interface that developers use indirectly, most generally through ContentResolver objects. You get a ContentResolver by calling getContentResolver () from within the implementation of an Activity or other application component.

6.5 Test results

As we are aiming to implemented Bluetooth auto-connection as a background process, it is hard to observe what is really going on in operation, but since every Bluetooth connecting was trying to establish will definitely consume power on the Smartphone. Detection results on power consumption while taking device away from Smartphone so that waits phone trying to establish connection process is illustrated in Figure 2.

Left graph is in the situation that there is no auto-Bluetooth connection function in the program, if may be a little hard to recognise, but the actually performance of the application is that when connection lost, Bluetooth will always search and attempt to find device, it continues consumes power at -349MA.


Battery Monitor Widget Pro

Charging USB plugged
Health:Good 27.0°C / 3763mV
Techno:Li-poly 705 / 1500mAh
Available:47% +428mA
Full estimation:2h47m (1h51m)

Visible: 1d 09:30:00 - Grid: 1h

Battery Monitor Widget Pro

Charging USB plugged
Health:Good 23.0°C / 3797mV
Techno:Li-poly 705 / 1500mAh
Available:47% +420mA
Full estimation:1h53m (1h53m)

Visible: 0d 09:30:00 - Grid: 1h

Figure 22 Power consumption without and with auto method

The graph on the right with lots of drops indicates application at a time instant was trying to connect. I believe this part is easier to understand while link the algorithm together. After automation method launched in to program, application will try to search once regarding to the algorithm, once the reconnection failed, application will postpone reconnection time for 10 minutes and then start over the process, here we only shows 4 times connection attempts with -179mA battery usage each time, after that Bluetooth successfully reconnected to device.

It's not hard to realise that with the Bluetooth auto connection function added to the application, even we can't guarantee the 100% reconnection rate. It somehow saves power for the application.

6.6 Bluetooth auto-connection stability

It's not hard to realise that with the Bluetooth auto connection function added to the application, even we can't guarantee the 100% reconnection rate, but It somehow saves power for the application.

We have to address here that the auto-connection function was not quite successful as what we expected. May be due to lack of experience of dealing with background debugging or knowledge about Bluetooth connecting problem we really hope in the future this problem can be solved.

The two reasons we are thinking brings out failure in connection would be:

- Sensitivity of “hot point” detection. “hot point” is the location determined by the values of longitude and latitude returned from handsets’ GPS system, from the research shown in figure we can see that the most precise civil GPS system usually have an error range of 30 meters, most of the mobile errors are much more higher than this, some situation will be worse if the handsets within indoor, tunnel, or urban area. They limit the performance of “hot point” reconnection method.
- It’s hard to detect Bluetooth loss. Currently we put packages received from device into database first then starts running application to access database , to get readings, the performance have to be like this as we must gather every single package, the program running speed is not matching the incoming package speed. Pre- stored in database is necessary. Detection method to decide if the device is still connected or not is according to check the package protocol format. (Header appears after Footer of last package inside database) Sensor device may occurs situations like sending chaotic messages, application crashes before detect connection lost is a major concern here.

7. Program optimization

This chapter we are more focusing on program performance and code management, since all the work done by this year will need to pass to followers. It's necessary that we ensure the performance of the application by doing debug and testing to minimise imperfections.

A good program should fulfil the following aspects:

- Simplicity: simplicity is reflected on program structure, concise code and functions. Simplicity of organise, implement and design your algorithm. Simplicity ensures bug free and reliable solutions.(Steve McConnel, 2010)
- Readability: means that others can read your code, includes comments, to follow conventions and pause to name variables wisely.
- Modularity: good programs erect large systems from smaller ones, which are built from even smaller building blocks. You can write a text editor with three primitives: move, insert, and delete. And just as atoms combine in novel ways, software components should be reusable. (Paul DiLascia, July, 2004)
- Design: Take time to plan your program before you build it. Thoughts are cheaper than debugging.
- Efficiency: means your program is fast and economical. It doesn't hog files, data connections, or anything else. It does what it should, but no more. It loads and departs without fuss. At the function level, you can always optimize later, during testing. But at high levels, you must plan for performance.
- Layering: program needs layers, like file-document-view-frame. Higher layers call ones below, which raise events back up. Lower layers should never know what higher ones are up to.
- Clarity: clarity of code, clarity of design, clarity of purpose. The fundamental challenge of programming is managing complexity. Simplicity, readability, modularity, layering, design, efficiency, and elegance are all time-honoured ways to achieve clarity, which is the antidote to complexity.

Therefore, a good program code is that strikes the right balance between all of the qualities mentioned above.

7.1 Program performance testing

In software development, performance testing is testing that is performed from one perspective to determine how fast some aspect of a system performs under a particular workload. It can also serve to validate and verify quality attributes of the system. It is importance to optimise the program while performance testing, developer should find out weakness and come up with remedy to solve problems.

During performance testing, it is crucial for the test conditions to be similar to the expected actual use, however, not entirely possible in actual practice. Performance tests in the sphere of our Android application should focus on the following two areas at this stage:

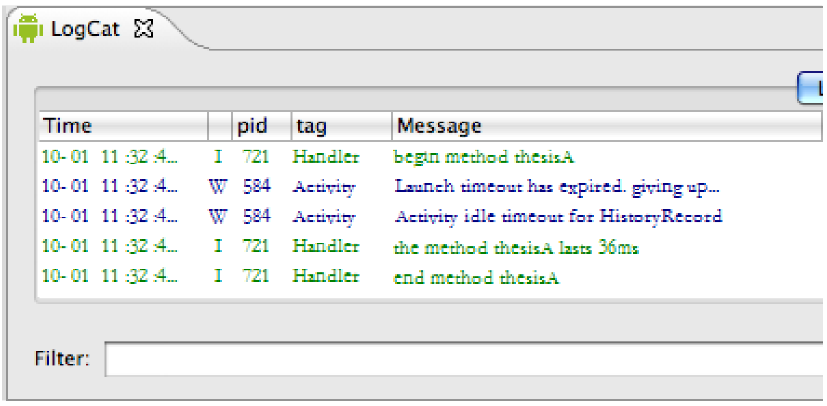
Memory consumption: mainly about memory cost while program running. We definitely do not expect high memory consumption of our application, as it will affect the phone functioning.

Program Computation time test: time requirements around a single activity to verify quality and capacity.

Other areas such as scalability; which is about how program deal with increase load flow and perceived performance; which is user's personal perspective towards the application should be carried out after the overall product is putting into market.

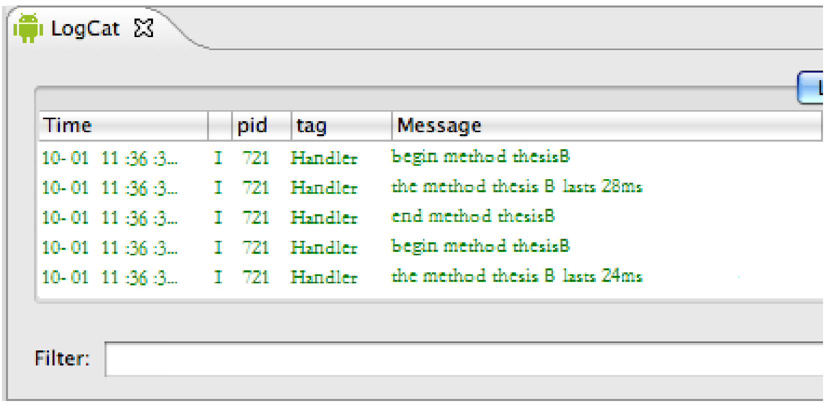
7.1.1 Program computational time test

Java language provides the "System.currentTimeMillis()" function in accuracy of millisecond returned current time for testing. Instead of put this line of code inside each function, we introduced Proxy design pattern, apply "java.lang.reflect.Proxy" class and "java.lang.reflect.InvocationHandler" interface, which makes up the heart of dynamic proxy's functionality.with DDMS interacts with Virtual Machine debugger, we will obtain the Log information clearly shows time of every function executed and ended.



```
Time            pid  tag       Message
10-01 11:32:4...  I  721  Handler   begin method thesisA
10-01 11:32:4...  W  584  Activity  Launch timeout has expired, giving up...
10-01 11:32:4...  W  584  Activity  Activity idle timeout for HistoryRecord
10-01 11:32:4...  I  721  Handler   the method thesisA lasts 36ms
10-01 11:32:4...  I  721  Handler   end method thesisA
```

Figure 23 Thesis A version program computational time screenshot



```
Time            pid  tag       Message
10-01 11:36:3...  I  721  Handler   begin method thesisB
10-01 11:36:3...  I  721  Handler   the method thesis B lasts 28ms
10-01 11:36:3...  I  721  Handler   end method thesisB
10-01 11:36:3...  I  721  Handler   begin method thesisB
10-01 11:36:3...  I  721  Handler   the method thesis B lasts 24ms
```

Figure 24 Thesis B program computation time screenshot

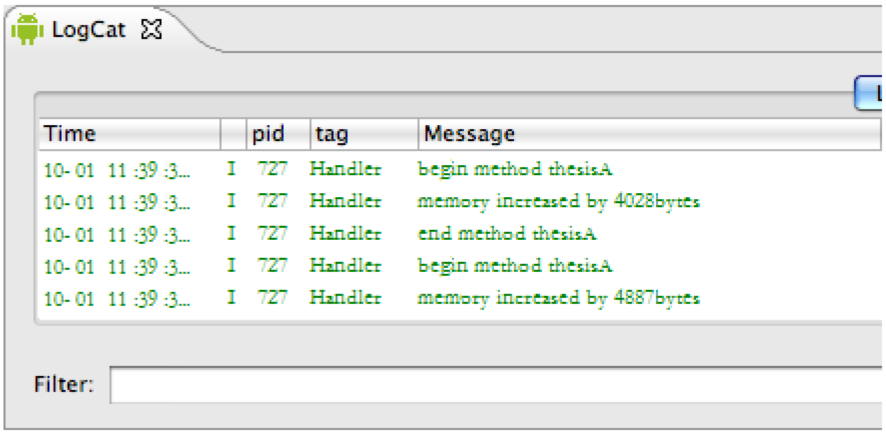
Log Cat is the selected tool in helping developer to view the internal logs of the android system, as viewing logs are the best way to diagnose problems, this way developer will find out what apps are doing in the background without noticing. Advantages of Log Cat

- Debugging
- You can see what processes are running, if a process is running after a certain interval of time, it will eat battery. So you can also find out what is draining your battery.

We used Log Cat to check program computational time and make a comparison between current version of runtime and previously thesis A work. Note here in figure 23 and 24 is that the current testing version of code do not includes Bluetooth auto-connection function, we can see that computation time decreases from 36ms to 24ms after program optimization carries out.

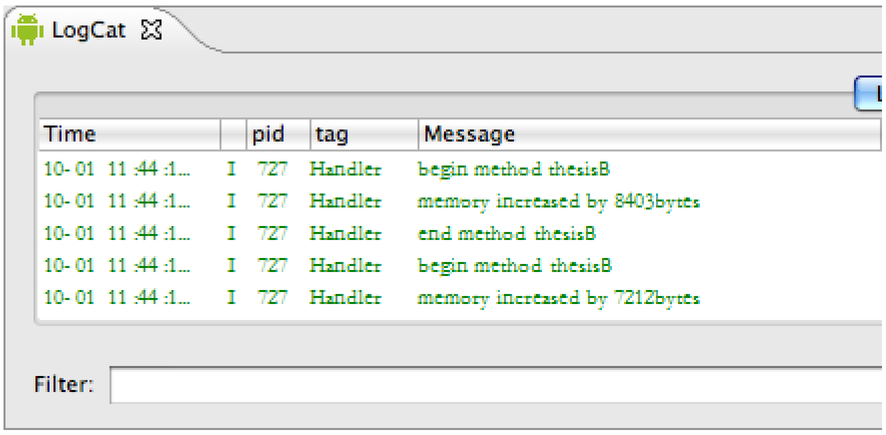
7.1.2 Memory usages test

One of the primary design goals for the Personal Java application environment is the minimization of the static memory footprint and the runtime memory usage. to check your code for efficiency or to approximate how many more objects of a certain type can be instantiated. To obtain these values, use the totalMemory( ) and freeMemory( ) methods.



```
Time               pid  tag      Message
10-01 11:39:3...  I  727  Handler  begin method thesisA
10-01 11:39:3...  I  727  Handler  memory increased by 4028bytes
10-01 11:39:3...  I  727  Handler  end method thesisA
10-01 11:39:3...  I  727  Handler  begin method thesisA
10-01 11:39:3...  I  727  Handler  memory increased by 4887bytes
```

Figure 25 Thesis A screenshot of memory test



```
Time               pid  tag      Message
10-01 11:44:1...  I  727  Handler  begin method thesisB
10-01 11:44:1...  I  727  Handler  memory increased by 8403bytes
10-01 11:44:1...  I  727  Handler  end method thesisB
10-01 11:44:1...  I  727  Handler  begin method thesisB
10-01 11:44:1...  I  727  Handler  memory increased by 7212bytes
```

Figure 26 Thesis B screenshot of memory test

As we can see from Figure 26, it shows the differences between the thesis A version and thesis B version, because in thesis B version we add Auto-connection method, this is the main reason that causes the increase of memory occupation, but with the help of program optimization, we believe that memory cost is still within an affordable range.

8. Java Language optimization

Sometimes the biggest problem with a program is that it requires simply too many resources, and these resources (memory, CPU cycles, network bandwidth, or a combination) may be limited. Code fragments that occur multiple times throughout a program are likely to be size-sensitive, while code with many execution iterations may be speed-sensitive as well. The aim of section is the apply rules in java programming to enhance the performance and efficiency of running application. These are the several common optimization techniques that apply regardless of the language being used.

- Loops: almost all speed problems involve loops, and the loop itself is an easy place to get a quick performance boost. The impact of the loop overhead depends on how many iterations the loop executes and how much it does during each iteration. Obviously, the more iterations and the less work done per iteration, the greater the benefit with optimizing the loop itself.
- Thread, objects, method: reduce the chance of stick inside one or two giant thread, object and method. A method that is long and complicated is difficult and expensive to maintain.

There are three performance optimization methods we carried out in our program improvement:

8.1 Use Object pool pattern to boost application speed

Java is in the domain of object-oriented programming, unlike simple or primitive data types that are just single pieces of information. Object-oriented objects are complex types that have multiple pieces of information and specific properties. Cost of creating and releasing an object is high; object pooling can offer a significant performance boost in such situations.

The general idea of object pool is it lets others check out objects from a pool, when those objects are no longer needed by their processes, they will be returned to the pool waiting to be reused. Pooling basically means utilizing the resources efficiently, by limiting access of the objects to only the period the client requires it. Increasing utilization through pooling usually increases system performance.

In our program the maximum amount of objects we required is 7 currently, mark the attribute of each element as “Used” or “reset” to indicates status, when application requires an object, just simple reset one ideal object in pool, after it released edits status as “Used” for later purpose.

8.2 Use basic data type to replace chances of creating objects to save space

Although creates objects seems more well-organized and nice structural in a program, but it is not a good behaviour to use objects holding every data in a program. Objects only requires when used expressly to package and transport a group of items when a generalised container is inappropriate. Objects also occupy large storage spaces than use basic data types such as int, char, and strings, therefore, used basic data type in some instance would be better than creating objects.

There are lot of cases in our program to use basic data type rather than objects. This behaviour is quite depending on programmer’s personal preference. The real time graphic plot is achieved by obtaining the two positions of X and Y axis’s coordinates.

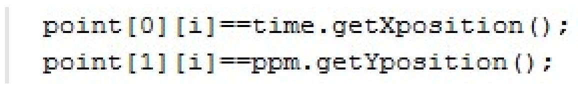

```
point[0][i]==time.getXposition();
point[1][i]==ppm.getYposition();
```

Figure 27 line code of obtaining position on graphic plot

Sensor readings transferred from device to Smartphone is firstly stored in a database; graphic plot maps the position of readings by pull out time and value by calling the figure 27 line of code. An array named point which is a basic data type is in use.

8.3 If two classes are associated with each other in some functional way, try to make one an inner class of the other.

This not only emphasizes the association between the classes, but it allows the class name to be reused within a single package by nesting it within another class. The use of inner classes will not uncouple the classes, but rather make the coupling explicit and more convenient.

9. Android program optimization[5]

Application based on android platform must be embedded. Modern handsets are not only a mobile phone, but also a portable laptop. Users are more expecting high performance and efficiency applications with high battery life circles.

We need to optimize application that gives the user the most convenience. Here we list some principles we applied to optimize the application: (David thesis, 2011)

1. Avoid creating object as far as possible:
2. Use self-function:
3. Use static instead of virtual:
4. Avoid use internal Get, Set function:
5. Carefully use "For-each" Loop:
6. Avoid Enumeration:
7. Avoid floating point type:

More detailed information of optimization in this chapter please refers to David Lu's report.

[5] Refer David's thesis

10. Calibrations in Haze watch system:

Calibration of gas sensors poses the greatest challenge for the long term outcome of the wireless sensor board. The method conducts last year for calibrating the sensors on each unit cannot ensure accuracy and system integrity; wrong calibration results will cause incorrect pollutant readings from the device and we cannot guarantee the whole system reliability.

Calibration is a process that is done in almost every medical, industrial, commercial product especially this product is used in measurements, it is the process of checking machines and making sure that values used in measurements remain at standard points, it is the process of verifying a machines work and performance within a set of specifications. (Chandra, 2011)

The carried out experiment for performing calibration equations of the three metal oxide sensors are comparing the measurements taken by both wireless sensor board and the Gas Alert Micro 5 Commercial meter. The resulting equations are estimated equations; the variations are quite large when calculating wireless sensor board output when exposes to high concentration gases. This discrepancy lacks of degrees of confidence about the calibration results and further investigation on calibration of those sensors should be taken place.

When calibration is done at the right way, calibration can make your life easier and better, it allows for faster processes and of course with lesser errors and mistakes. During calibration, it is also important to make sure that the measurements taken during the period is also valid. Whatever values that we have gotten during the calibration process should be the values that are accepted to be the most accurate and precise.

10.1 Method 1: Experimentally doing calibration using pure gas cylinders

This method was firstly suggested by Dr Martin Bucknall from Bio-analytical Centre.[6] The overall idea scope was illustrated in Figure 1; the gas container (Tank) is made by plastic material， the lid (made by plastic as well) was sealed by o-ring on top and give it a screw, the lid will tightly on; this is to insure no air leakage for the Tank; a septum is drilled on the side of the plastic container; a commercial meter and 6 devices will be putting inside the tank one near another for the purpose of taking readings. A commutator free fan will be attached on the side of the Tank to mix up the injected gases.

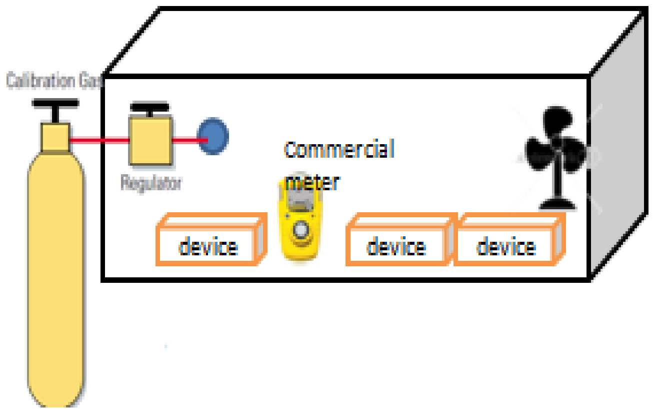


Figure 27 Calibration method 1 overview

The general ideas is to inject certain small amount of calibration gases to the Tank, the Gas Alert Micro 5 Commercial meter works as a standard reading, data collected from devices will compare with that reading to form a calibration equation for each sensor. All the desired features of the Gas tank are being built at school workshop, the next step would be purchase gas cylinders with mixture of the target gases,

Up to here our method of doing calibration is simple, unlike laboratory analyzers that require a high degree of accuracy. For area air quality and safety gas monitors, the requirements need to be simple, repeatable, and economical.[7] The procedure should be consistent and traceable. The calibration will be performed in the field where sensors are installed so it can occur in any type environment. However, it is most important to keep the calibration methods standardized and easily traceable.

According to World Health Organization's air quality and health specification and the capability of sensor specifications we obtained the guideline values of each gas:

Gas name	WHO Guideline values (ug/m^3)	PPM	SENSOR CAPABILITY Range
Ozone (O_3)	100ug/m^3 (8 hrs mean)	0.05ppm	0.01 -1PPM
Carbon monoxide (CO)	100mg/m^3 (15min) 35mg/m^3 (1 hr) 10mg/m^3 (8 hrs) 7mg/m^3 (24 hrs)	87.33 ppm 30.568 ppm 8.7336 ppm 6.1135 ppm	1 -1000PPM
Nitrogen dioxide (NO_2)	40 ug/m^3 (annual mean) 200 ug/m^3 (1hr mean)	0.02128ppm 0.10638ppm	0.05 TO 5 PPM

Table 2WHO Guidelines of pollutant levels

From table 1, we will observe that all the metal oxide sensors in our devices have the measurable capability within range of WHO guidelines. Based on table 1 we decide the measurement ranges that are most suitable for calibration effort:

- CO: 0 to 200 ppm, go in increments of 10ppm
- NO2: 0 to 1 ppm, go in increments of 0.05ppm
- O3: 0 to 5 ppm, go in increments of 0.05ppm

Therefore under the calculation help of Dr Martin, our purchase list would be:

- For CO, we should get pure gas. If we inject 2.8ML into the tank, that will be 200 ppm.

[7] http://www.permapure.com/wp/wp-content/uploads/calibration.pdf

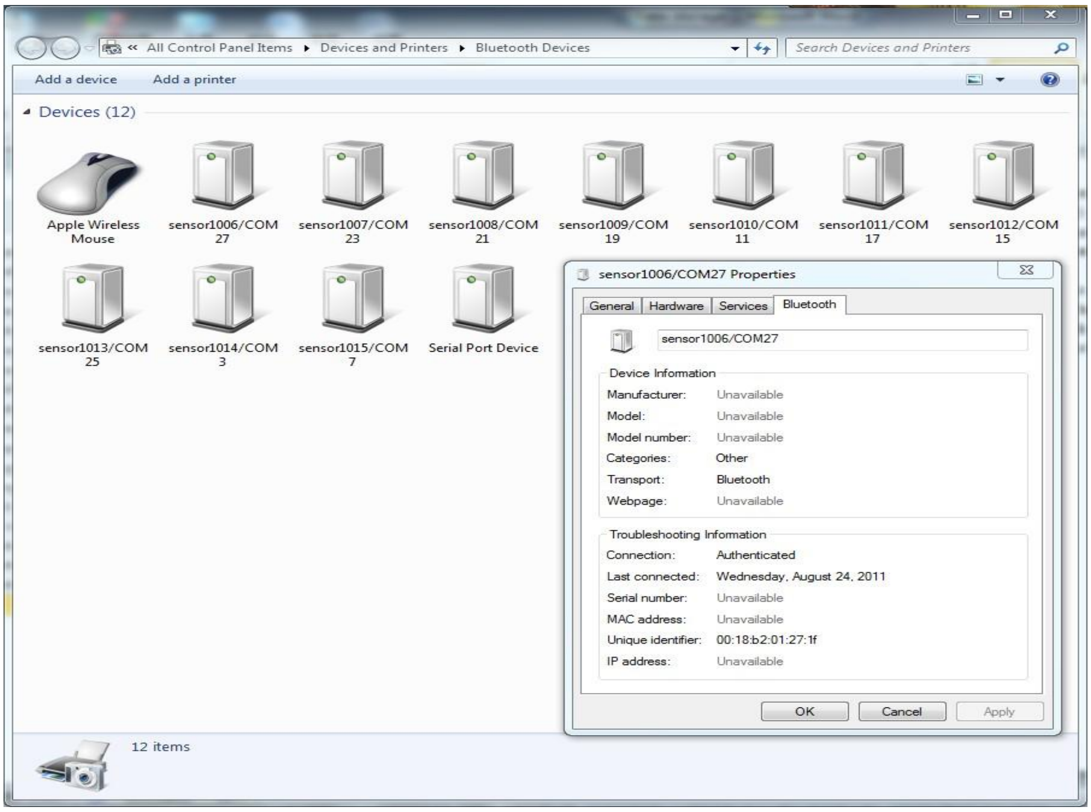
- For NO2, we should get 10000PPM diluted in air or nitrogen. If we inject 1.4mL into the tank, that will be 0.5 ppm.
- For O3, we should get 5000 ppm diluted in air or nitrogen. If we inject 1.4ML of this in to the tank, that will be 0.5 ppm.

All injection of sensible volumes will use syringes as suggested by Dr Martin to ensure accuracy.

During the preparation of purchasing those gas cylinders, we get the reply from E2V Company who manufactured the metal oxide sensors, they suggested that we may do two point calibration method. The two point usually zero and the point of our standard gas. For example: to calibrate CO, firstly we put the sensor in the ambient air to record the output as the zero and then to give like 50ppm or 100ppm CO through the sensor and then record the output. With these two points, we can get the characterization line of the sensor, and then we can get the concentration from the sensor output at different concentration. As sensor may drift, the intervals between calibrations can be different from sensor to sensor. Generally, the manufacturer of the sensor will recommend a time interval between calibrations. However, it is good general practice to check the sensor more closely during the first 30 days after installation. During this period, it is possible to observe how well the sensor is adapting to its new environment.

The two companies we have contacted to purchase gas cylinders are BOC and Liquid as suggested. We came across difficulties and concerns about not only in budget but also about the commercial qualification after we perform the calibration process, is it accurate of doing calibration in this way, we are not expertise in such area, we cannot guarantee and convince others we are getting the correct data. From this point we are thinking if there exist any company that is already qualified would able to help us doing calibration and ensure reliability.

In this method we need to obtain values of each sensor unit via their Bluetooth transmission. Mat lab works as a bridge between data transmission and receiving between device and PC Bluetooth, initially we only achieved connecting one device at a time and the common port always changes while running Mat Lab code. After some research and spending some time on it, we are able to bind a single device unit to one certain port so that during Mat lab running we can switch each connection in a loop to obtain every device output and save in a file. Figure 28 is a screenshot of 11 devices bind with fixed common port.



sensor1006/COM27

Device Information

Manufacturer: Unavailable
Model: Unavailable
Model number: Unavailable
Categories: Other
Transport: Bluetooth
Webpage: Unavailable

Troubleshooting Information

Connection: Authenticated
Last connected: Wednesday, August 24, 2011
Serial number: Unavailable
MAC address: Unavailable
Unique identifier: 00:18:b2:01:27:1f
IP address: Unavailable

Figure 28 Bluetooth binding inside PC

10.2 Method 2: e2v Gas Sensor Evaluation Kits

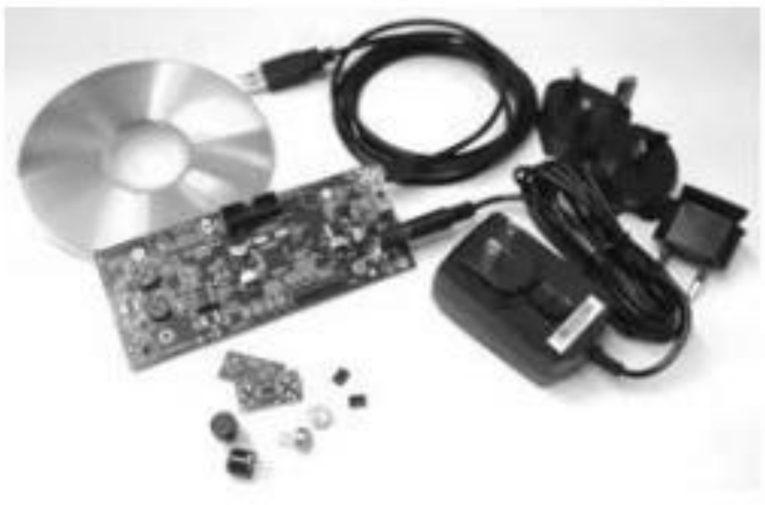


Figure 29 E2v metal oxide semiconductor gas sensor evaluation kit

After getting response from some company that manufacture and calibrated different sensors, we realise that once the company produce a particular product (gas sensors) that requires calibration and adjustment, they must create the product that can do this sort of work for people at the same time. As lots of the companies in Sydney say that they can help us with calibration of our sensor, but since they are not the manufacture company and we designed our own board in a way that they can't really guarantee the calibration procedure will be correct. Luckily E2v Company replies with good news that they have the evaluation kits particularly for those metal oxide sensors.

Figure 2 is the components contains in the evaluation kits, using this kit, simply attach it to power supply and connect your PC USB port and plug in one or two gas sensors, the software in the disk will log and control the performance of different sensors to be assessed and makes life easier to capture performance data in a purpose of calibration.

So far the sensor unit device is self-designed and built; there exists some discrepancy and weakness along the thesis work carried out by our group work.

- ADC (analogue to digital converter) output error digital value compare to input voltage
- Message Protocol format sometimes messes up that leads to android phone application crash
- Sensor voltage output does not match pin settings in the microcontroller. For example in session 3.2 we introduced the message format, the sensor values are sent in format 1 (Indicates ozone) followed with readings, 2 (Indicates CO) followed with readings, 3 (Indicates NO2) followed with readings. It is believed that all the readings from each sensor should match its corresponding coordinates, but currently we find out it is not.

The idea of using this evaluation kit in the future would be:

1. The evaluation kit has a JTAG header which allows advanced users to upload their own software to the microcontroller (MSP430F2616) and make full use of the available interfaces. Once make sure the evaluation kit could help and easy understandable, microcontroller coding should carried out to form message format and output it out.
2. Attach Bluetooth unit into the evaluation kit or elsewhere designed board with the principle of evaluation kit, so that it can transmit out the message package for Smartphone to collect the information.

There will definitely a lot of more difficulties will come across that we can’t imagine, but as long as the design is based on the evaluation kit, it would be easier to seek help at the E2v company.

If the evaluation kit solves the weakness of the current designed board and also able to help with the calibration, it would be a perfect choice to have this kit around with this project。

11. Future work

Hardware

The most important work in future would be calibration of the hardware sensors; in the report I have suggested two ways of doing calibration. The sensing unit device is the most basic element in Haze watch system, without a correct functioning and reliable outputs from the hardware device; we can't convince users and clients that this overall "Haze watch system" is useful and accurate. Some of the problems of hardware device are indicated in session 10.2.

Software

There are lots factors can affect the stability of our application, like data message format error, Location server lost or temporary shutdown in purpose of maintain, It needs more field test and debug to improve the stability, and as there must still have unknown factors may cause the application crash, it need a function to record the operation statement and error, for the purpose of future development.

According to user requirements, certain features and functions still need to be adding to application, Bluetooth loss detection and connection at this stage is not functioning perfectly, further work should carry out as well. Mode operation only divides conditions in terms of speed; further considerations are more expected.

Confidence level

The results of tests we conducted of location tacking are occasionally fairly poor, indoors or on roads with many overhanging trees will lead application fails to receive GPS signal at all. A prudent improvement for the future would be to filter out inaccurate locations.

Privacy

Taking about collecting data, the almost-real-time location of that user is periodically uploaded to the server. This information could be used by an eavesdropper in nefarious ways, and is a breach of the user's privacy. To prevent this type of attack, the information could be encrypted before being sent such that the server is the only party able to decrypt the information. An RSA public/private key pair system could be one possible solution to this problem.

12. Conclusion

Current systems in place to monitor air pollution levels typically have only a handful of fixed monitoring stations distributed over an entire city. There is a need for higher resolution, cost effective air pollution data to inform any interested members of the general public, the proposed Haze watch system is being developed.

Using motor vehicles as a platform for our hardware, the haze watch system utilises existing internet to enable Smartphone to act as a bridge to transmit air pollution readings to our server.

The work undertaken at this stage about "Haze Watch system" project has shown how it works in a way to pollution monitoring. Through the use of a network of mobile air pollution sensors, database for all pollution samples, and some applications it is believed that, this system can help the public and society to improve in health and environment awareness.

The main focus in this report is about interface design. Works undertaken at this stage still lie to the fundamentals of the "Haze watch system", which implies that a lot more modifications and changes are expected in the further. The results of interface features we have conducted so far have proven that the basic android application we set out to implement in this phase is operational and is producing reasonable results.

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14. Appendix A

Bluetooth and mat lab interface code

```
function []=calibration(com_number,filename)

%
%
sensor = serial(com_number);
set ( sensor, 'BaudRate', 9600);
set (sensor, 'Terminator', 45);
fID=fopen(filename,'w');
fopen(sensor);
    Sensor0 = 0;
    Sensor1 = 0;
    Sensor2 = 0;
    Sensor3 = 0;
    Plotsamples = 100;
    x1 = zeros(1,Plotsamples);
    x2 = zeros(1,Plotsamples);
    x3 = zeros(1,Plotsamples);
    i = 1;
    countt = 0;

while(countt~=10)

  count = 1;
  voltage1total = 0;
  voltage2total = 0;
  voltage3total = 0;
  samples = 1;
  while (count <= samples)

 buffer = fread(sensor,1);
 while( buffer == 255 || buffer == 238)
     buffer = fread(sensor,1);
 end
 if (buffer == 00) % Sensor 1
     Sensor0 = fread(sensor,1);
     buffer = fread(sensor,1);
 end
 if (buffer == 01) % Sensor 1
     Sensor1 = fread(sensor,1);
     buffer = fread(sensor,1);
 end
  if (buffer == 02) % Sensor2
     Sensor2 = fread(sensor,1);
     buffer = fread(sensor,1);
  end
  if (buffer == 03) % Sensor 3
     Sensor3 = fread(sensor,1);
     buffer = fread(sensor,1);
  end
    voltage0 = Sensor0/255 * 3.3;
    voltage1 = Sensor1/255 * 3.3;
    voltage2 = Sensor2/255 * 3.3;
    voltage3 = Sensor3/255 * 3.3;
       fprintf('here\n');
```

```
        fprintf(fID,'%f    %f    %f\n',voltage1,voltage2,voltage3);


        voltage1total = voltage1total + voltage1;
        voltage2total = voltage2total + voltage2;
        voltage3total = voltage3total + voltage3;
        count = count + 1;
      end


        voltage1 = voltage1total/samples;
        voltage2 = voltage2total/samples;
        voltage3 = voltage3total/samples;

        resistance1 = (10000*5)/(5-voltage1);
        resistance2 = (10000*5)/(5-voltage2);
        resistance3 = (10000*5)/(5-voltage3);

        %pollution1 = 0;
        %pollution2 = 0.0405*exp(5.2621*voltage2);
        %pollution3 = 0.0405*exp(5.2621*voltage3);

        pollution1 = voltage1;
        pollution2 = voltage2;
        pollution3 = voltage3;

           count = 0;
           countt=countt+1;
    end

    fclose(sensor);

    end
```