Community Sensor Networks: An Application to Pollution Maps
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Abstract

Air pollution is a widely recognized threat to our health and the environment in which we live, and can seriously hamper visibility. As currently implemented, air pollution monitoring is based on environmental monitors sparsely deployed at a relatively small number of fixed locations by governmental organizations to develop maps revealing pollution patterns across cities. This lack of pollution monitoring coverage needs to be addressed through complementary technologies, systems and strategies. This paper proposes the use of community sensor networks for the measurement and distribution of air pollution levels. It also proposes the web-based publication of the resulting pollutions maps to promote public participation in the fight against the health and environmental challenges associated with air pollution. The main contributions of this paper are twofold. Firstly, we extend a recently proposed Ubiquitous Sensor Networking (USN) architecture proposed by the ITU in the context of the Internet of the Things (IoT) to propose the main networking architecture behind community sensor networks. Secondly, building upon off-the-shelf sensor devices and existing web services, we present the experimental results and pollution maps built in the city of Cape Town in South Africa as a proof of concept on how community sensor networks can be built using least cost equipment and how pollution maps can be derived from the pollutant levels collected through these networks.

1. Introduction

It is widely recognized that as a result of the emission of gas, liquid vapor, or solid particulate matter into the atmosphere by human activity, sufficient increases in the concentrations of various ambient pollutants in the air may become a threat to both our body and our environment and also limit visibility. These high concentrations of pollutants may have consequences that can (1) aggravate health problems for the elderly and people with other health impairments such as heart and respiratory diseases, cause
cancer, birth defects, long term injury to lungs as well as brain and nerve damage (2) damage our natural environment, such as trees, crops, other plants, lakes, and animals (3) damage buildings, monuments, and statues and (4) interfere with aviation and road traffic as well as reducing our vision in national parks and cities. Instances of catastrophic pollution episodes revealing the dangers that air pollution poses to public health have been reported in the literature [1] [2]. These include the air pollution formed above the industrial town of Donora, Pennsylvania, in October 1948 that built a thick cloud of air pollution which lingered for five days; killing 20 people and causing illness in 6,000 of the town’s 14,000 people. Another event that became known as the London’s ”Killer Fog” happened in 1952 killing over 3,000 people due to a smog that was so thick that buses could not run without guides walking ahead of them carrying lanterns. The Meuse Valley fog is another case of an air pollution disaster that occurred in the Meuse Valley near Liege (Belgium) early in December, 1930 in the form of a mysterious fog disaster involving several thousands of cases of illness and 60 deaths caused by acute fluorine intoxication. This was caused by factors in the region developing gaseous fluorine compounds (SiF4, HF) from raw products containing fluorine (superphosphate works, zinc works) or adding fluorine compounds to the raw materials (steel works, iron foundries, glass works) and passing these compounds into their chimney smoke with the occurrence of special climatic and topographic conditions favoring the development of the disaster. It is also recognized that although not all types of air pollution have a negative impact on climate change, some types, such as those involving the emission of carbon dioxide from cars and trucks, may speed up global warming. It is also know that some primary pollutants may undergo chemical transformations under UV radiation leading to the formation of secondary pollutants. An example of such a secondary pollutant is ozone (O3) [3], [4], which, when in the stratosphere (between 6 and 30 miles above the earth’s surface), plays an important role in screening out harmful ultraviolet radiation from the sun and thus helping to prevent health problems like skin cancer, but can have detrimental effects on the eyes, nose, throat and lungs when found at ground level and indoors.

The mitigation of air pollution in urban areas is implemented through regulations, the setting up of programs and policies, the promotion of activities that reduce air pollution, and the use of cleaner and less polluting technologies to aids mitigation and reduce the levels of pollutant in the air. Air pollution and its devastating impacts prompted the USA to erect laws such as the Clean Air Act [5] and commission agencies such as the Environmental Protection Agency (EPA) [6] with the task of cleaning up of air pollution. The Clean Air Act requires EPA to set National Ambient Air Quality Standards for six common air pollutants that can harm US citizen health and their environment, and cause property damage [7]. These air pollutants commonly found in the USA include Ozone (O3), Particulate Matter (PM), Carbon Monoxide (CO), Nitrogen Oxides (NO3), Sulfur Dioxide (SO2), and Lead. They are referred by EPA as criteria air pollutants because they are used to set setting permissible levels in the development of human health-based and/or environmentally-based criteria. While the set of limits based on human health are called primary standards, the set of limits intended to prevent environmental and property damage are called secondary standards.
1.1 Participatory Sensing

Participatory sensing is an enabling technique which can be used to support the air pollution mitigation process by integrating citizens and community groups into the environmental monitoring community to help expand current air pollution maps. This will allow data collected from private personal observations of hundreds, or even thousands, of individuals to be integrated into city pollution maps with better resolution. As described by [9], [10], [11], [12], a participatory sensing system is one that starts and ends with people both as individuals and members of communities to allow individuals and communities to collect, share and organize information using cell phones and other mobile platforms, with the objective of making a case for change and exploring and understanding their life and relationship with the environment. Participatory sensing has adopted mobile phones as key devices in sensing the local environment because of (1) their sheer ubiquity across the demographic and geographic spectrum (2) the broad proliferation of cellular infrastructure and mobile phone usage making it possible to collect data over large areas for little incremental cost (3) the possibility for participants scattered across a city or the world to easily coordinate activities and upload data to servers that can process it and integrate it with other data and (4) the possibility for most modern phones to record images, motion, and other signals, automatically associating them with location and time.

Figure 1: The AIR Device

Figure 1 shows a participatory sensing example where a custom board, called the AIR device, [13] is fitted with carbon monoxide (CO), ground level ozone (O3), Nitrogen Oxides (NOx), temperature, and humidity sensors and includes a Bluetooth module that connects the handheld device to the user’s own mobile phone. The handheld device is typically attached to a bag, backpack, or belt-loop and uses the EPA’s database of nation-
wide polluters as source of information. As opposed to the highly sensitive but geographically spread fixed monitoring devices used by the U.S. government to measure its Air Quality Index (AQI) [15], it can be credited to the AIR devices the capability of providing better resolution by recording the range of pollutant levels within a small geographical area (block-to-block) experienced by a person over a short period of time (several minutes interval).

Building upon the participatory sensing model, pedestrians, cyclists, buses and cars were turned into mobile wireless sensors and used in conjunction with 12 static sensors in a bid to measure London’s air quality on the 30th June 2009. This was done with pocket-sized sensors carried by pedestrians and cyclists to map levels of pollution and observe how the pollution moves. These sensors were developed in the context of the MESSAGE project [14] to measure traffic pollutants, and detect car pollutants and other contaminants. Using the wearer’s mobile phone, pollution levels were transmitted to a processing station, while tagging locations using Google Maps. The project goal was to develop and demonstrate the potential of diverse, low cost sensors to provide data for the planning, management and control of the environmental impacts of transport activity at urban, regional and national level. The project achieved this by integrating three sensor platforms into a common data processing platform: (1) personal devices (mobile phones) to support a sensing system (2) a smart-dust network using Zigbee (IEEE 802.15.4) motes, and (3) a network utilizing WiFi (IEEE 802.11.g) and WiMax (IEEE 802.16) technologies for communications and positioning and (4) a set of novel sensor designs.

1.2 Contributions and Outline

The availability of data on important phenomena such as air quality could enable important advances in medicine, science, and policy. However, collecting this data raises issues:

**Problem of equipment.** Many developing countries are not yet equipped for air pollution measurement and when these measurements are available, they are often so inaccurate that it is not possible to get even a rough estimate of the abundance of pollutants in these regions and their impact on diseases such as asthma, cardiovascular diseases and bronchitis.

**Visibility gap.** As currently implemented, air pollution monitoring uses large stationary sensors sparsely deployed at relatively a small number of fixed locations by governmental organizations. The small number of locations at which these sensors are found and the subsequent inability to provide enough information creates a visibility gap that needs to be addressed through complementary technologies, systems and strategies.

**Cost and accuracy.** Stationary pollution sensors are usually based on satellite instruments which are too expensive for some developing countries. They also generally struggle to achieve accurate measurements of some of the pollutants such as particle matters in near-surface air. This is because (1) most of them can’t distinguish particles close to the ground from those high in the atmosphere (2) satellite views tend to be obscured by clouds and (3) bright land surfaces, such as snow, desert sand, and those found in certain urban areas can mar satellite measurements.
This paper proposes the use of off-the-shelf devices and the participation of the civil society to build community sensor networks (CSNs) for the collection of air pollutant data in cities and advocates the use of web services to publish this data in order to promote public participation in the fight against air pollution and its devastating impacts. The main contributions of this paper are twofold. Firstly, we propose the main networking architecture behind community sensor networks. This architecture extends the recently proposed USN architecture proposed by the ITU in the context of the Internet of the Things (IoT) [17]. Secondly, using an experimental Testbed, we present pollution maps built in the city of Cape Town in South Africa as a proof of concept of how Community sensor networks can be built using off-the-shelf sensor devices and pollution maps can be derived from the pollutant levels collected through these networks. Our experimental setting reveals that using a combination of off-the-shelf sensor equipment, Zigbee and GPRS protocols, and web services such as Google Maps, community sensor networks can be built to produce pollution maps used to inform citizens and organizations on the levels of pollution in cities and their impact on health, environment and visibility.

The remainder of this paper is organized as follows. Section 2 presents the main ideas behind community sensor networks and describes both the networking architecture behind these networks and the Testbed used to build pollution maps in the city of Cape Town. Section 3 describes and discusses our experimental results while our conclusions and directions for future work are presented in section 4.

2. Community Sensor Networking

A common vision of community sensor networking (CSN) consists of launching sensing devices into distinctly common-place spaces such as markets, hospitals, streets, farms, rivers, lakes, rivers, road sides, and workplaces and mounting other devices on cars, trains and other moving objects to sense our daily living environment and deliver different services in a heterogeneous environment involving a number of applications, protocols, operating systems, processors, and architectures. To promote public participation in environmental monitoring activities, such as the fight against pollution, climate change and other natural disasters like droughts and earthquakes, the CSN model promotes the use of least-cost off-the-shelf devices to enable ordinary citizens to easily take measurements and report what is happening in their environment through web-based publication of the environmental maps (temperature, pollution, humidity, particle matter, etc.). The CSN implementation process thus involves (1) collection of environmental data using sensors (2) analysis of this data and modeling of environmental changes in cities and countries (3) awareness to citizens, official organizations, Non Governmental Organizations and private organizations and (4) derivation of sound policies based on the derived environmental models. While participatory sensing promotes the use of mobile
phones as environment sensors, community sensor networking relies on an emerging sensor/actuator technology where sensing devices equipped with GPS, GPRS, a set of sensors and WPAN communication protocols. These mobile sensor devices are capable of sensing the environment and using the extensive GSM network to transfer the environmental data to processing centers where the data will be analyzed and processed, enabling appropriate action to be taken about the environment being monitored. Such devices are also able to use the ZigBee protocol or any other emerging WPAN protocol such as 6LoWAPN [16] to achieve information dissemination.

### 2.1 A Multi-Layer CNS Architecture

Figure 2 illustrates the schematic layers of a multi-layered network architecture used for the implementation of Community Sensor Networks (CSNs). This network architecture reveals different layers used to provide different services to different types of applications in a multi-technology, multi-devices and multi-protocol platform.

![Figure 2: The CSN Architecture](image)

It reveals (1) a sensor networking layer (the bottom layer) where sensor and, if needed, RFID devices are launched into the environment to sense and identify what is happening and report to sink nodes via USN bridges (2) A CSN access networking layer (the second layer) where the combination of CSN bridges and sink nodes are used as an access network for the first-mile connectivity of a Next Generation Network (NGN) of gateways (3) a CSN middleware layer (third layer) is used as an interface between the NGN and the applications layer and (4) different applications are embodied into a CSN applications layer (the last layer) to perform tasks related to logistics, structural health monitoring, agriculture control, disaster surveillance, military field surveillance and disaster/crisis management. The community sensor networking scenario depicted by Figure 2 is built around a communication platform using (1) different protocols such WiFi, wireless LAN and PAN technology, code division and time-division multiple access wireless communication protocols (2) different devices which are based on different processors such various types of PDAs, smart phones and laptops and (3) all these protocols and devices being built around different architectures such as centralized, distributed or peer-
to-peer. In contrast of the USN architecture proposed in [17], our CSN architecture includes (1) a multi-layer access networking layer supporting delay-tolerant communication (2) a multi-layer Middleware layer supporting sensor system adaptations such as translation from voltage to temperature and information adaptations such as speech conversion from English to a local language and (3) different other key features embedded in the different layers of the CSN architecture.

### 2.2 A CSN Implementation Model

Wireless sensor nodes (or motes, as they are commonly called) are traditionally used to provide a quasi static sensing infrastructure where the motes are launched into the environment and probed periodically to measure changes in the environment variables. These changes are reported to processing centers where environmental maps (temperature, humidity, pollution, etc.) are built and decisions are taken on the environment being controlled. WaspMotes are a new generation of wireless sensor motes which have been recently released by Libelium [19]. They are built around the XBee transceivers [20] which provide several advantages over other devices, in terms of multiplicity of operating power, protocols, and operating frequencies, as depicted by the XBee features in Table 1.

<table>
<thead>
<tr>
<th>Model</th>
<th>Protocol</th>
<th>Frequency</th>
<th>TX power</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>XBee-802.15.4</td>
<td>802.15.4</td>
<td>2.4 GHz</td>
<td>1 mW</td>
<td>-92 dB</td>
</tr>
<tr>
<td>XBee-802.15.4-Pro</td>
<td>802.15.4</td>
<td>2.4 GHz</td>
<td>63 mW</td>
<td>-100 dB</td>
</tr>
<tr>
<td>XBee-ZB</td>
<td>ZigBee-Pro</td>
<td>2.4 GHz</td>
<td>2 mW</td>
<td>-96 dB</td>
</tr>
<tr>
<td>XBee-ZB-Pro</td>
<td>Zigbee-Pro</td>
<td>2.4 GHz</td>
<td>50 mW</td>
<td>-102 dB</td>
</tr>
<tr>
<td>XBee-868</td>
<td>RF</td>
<td>868 MHz</td>
<td>315 mW</td>
<td>-112 dB</td>
</tr>
<tr>
<td>XBee-900</td>
<td>RF</td>
<td>900 MHz</td>
<td>50 mW</td>
<td>-100 dB</td>
</tr>
<tr>
<td>XBee-XSC</td>
<td>RF</td>
<td>900 MHz</td>
<td>100 mW</td>
<td>-106 dB</td>
</tr>
</tbody>
</table>

Table 1: XBee Transceivers.

Other WaspMote characteristics include (1) minimum power consumption of the order of 0.7µA in the Hibernate mode (2) flexible architecture allowing extra sensors to be easily installed in a modular way, and (3) the provision of GPS, GPRS and SD card on the board. Furthermore, WaspMotes are powered with a lithium battery which can be recharged through a specially dedicated socket for the solar panel; this option is specially interesting for deployments in remote environments. Further advantages of using WaspMotes include the capability of using security features based on the four kinds of transmission modes: (1) Unicast without encryption, (2) Unicast with encryption, (3)
Broadcast without encryption and (4) Broadcast with encryption. Waspmotes can use different means of radio communication to send data to a gateway where measured data are stored. When deployed in a community sensor networking setting, several Waspmotes can be equipped with external GPRS modules and use the ubiquitous GSM network to send data either as SMS or with a GPRS data connection. They can also be equipped with different 802.15.4/ZigBee transceivers while also simultaneously hosting a GPRS module which, when programmed, is capable of sending and receiving SMS, making and receiving calls and connecting to the GPRS network to transfer data. Figure 3 depicts the WaspNet Testbed system. WaspNet uses Waspmotes and builds upon the CSN model and the multi-interfacing capability described above to sense the environment, disseminate the sensed data and create pollution maps.

3. Experimental Results and Discussion

As proposed in its experimental phase, WaspNet uses two different mote configurations. In both configurations, Waspmote main board is used in conjunction with a gas board and GPS board while information dissemination is achieved using either (1) a GPRS module and a Telit GC864 GSM modem [21] interface to mobile network when using the GRPS mode or (2) a Waspmote XBeePro module and a Waspmote XBeePro gateway when operating in the ZigBee mode, as depicted by Figure 3. Both configurations use a SD Card to store readings if either the GSM or Zigbee networks are not available at the time when the reading is taken. Then, when the presence of the respective data network is detected, all the outstanding stored readings are uploaded to the WaspNet gateway. This mechanism provides the robustness required for the CSN model to function effectively.

Figure 3: The WaspNet Testbed System
3.1 The gas board and experimental setting

Figure 4: The Gas Board (source Libelium)

The Waspmote gases sensor board depicted by Figure 4 has been designed to monitor environmental parameters such as temperature, humidity, atmospheric pressure and 11 different types of gases. It allows the inclusion of 6 gases sensors at any one time, the regulation of their power through a system of solid state switches and the amplification of the output signal through a controllable amplifier. The gases which can be monitored are (1) Carbon Monoxide CO, (2) Carbon Dioxide CO2, (3) Molecular Oxygen O2, (4) Methane CH4 (5) Molecular Hydrogen H2 (6) Ammonia NH3 (7) Isobutane C4H10 (8) Ethanol CH3CH2OH (9) Toluene C6H5CH3 (10) Hydrogen Sulphide H2S and (11) Nitrogen Dioxide NO2.

- **Nitrogen dioxide (NO2):** it is a gas produced by the rapid oxidation of NO, which is produced by burning fossil fuels in vehicles and industry. It is a toxic and irritating gas that affects the respiratory system and also encourages the production of nitric acid (HNO3) responsible for acid rain.

- **Carbon dioxide (CO2):** it is a gas naturally present in our atmosphere. Together with water vapor and other gases is one of the greenhouse gases that regulate Earth's temperature. Production in excess as a result of increased fossil fuel usage could have a direct impact on climate change.

- **Carbon monoxide (CO):** it is produced in incomplete combustion, ie, when part of the fuel does not react completely due to a lack of oxygen. Its danger to humans and animals, once it sets in blood hemoglobin, it prevents oxygen transport, which can be lethal. Although in open space is easily diluted, the CO emission from the engines of cars in congested areas causes may have rates of 50-100ppm, which are dangerous.
• **Methane (CH4):** it is produced when organic materia decomposes in oxygen-poor environments. As carbon dioxide, it is a greenhouse gas so its increase may contribute to global warming.

• **Hydrogen sulfide (H2S):** it is emitted into the atmosphere by various industries, such as paper. It is particularly dangerous because it is a highly toxic gas and it is a sulfur dioxide precursor, one of the gases in the processes of formation of acid rain. In addition, this gas is specially annoying because of its foul smell.

• **Hydrocarbons (Ethanol, Propane, Butane, Isobutane, Toluene):** they come from various sources, such as poor combustion of gasoline and diesel or industrial processes. They are, among others, responsible for greenhouse effect and contribute to produce respiratory problems.

• **Ozone (O3):** it is a natural constituent that can be found at sea level with a concentration of 0.01 mg / kg. However, with intense solar radiation and high contamination coming from vehicles, its concentration can go up to 0.1 mg / kg being dangerous. In this proportion, the plants may be affected and human may experience irritation of nasal passages and throat and dryness in the lining of the respiratory tracts.

To improve the accuracy of these sensors, a calibration procedure can be used, in effect creating a "clean air" baseline against which gas presence levels can be measured. This calibration procedure consists of taking a number of readings in clean air, and averaging the raw resistance values recorded.

Building upon the WaspNet Testbed, we conducted sets of experiments to assess the readiness for field deployment of the system in terms of (1) pollution level measurement and mapping and (2) information dissemination using both ZigBee and GPRS connectivity when measuring pollutant levels in the city of Cape Town, and publishing the results as pollution maps using Google Maps. We conducted experimental trials using both WaspNet mote configurations, with both devices being carried in a car driving in defined target areas. We conducted three sets of trials during the experiment: one on the 23 July 2010, the second on 24 September 2010, and the third on 29 September 2010. For the first set of experiments conducted on the 23 July, we used as starting point (as the source for the calibration) a house located in leafy and low-density population suburb called Fernwood, near the National Botanical Gardens. All subsequent readings were relative to the air pollution levels at this house. The second and third sets of experimental trials were conducted on the 24th and 29th of September 2010, both using as starting point the higher campus of the University of Cape Town as the calibration point. The first and third trials targeted primarily the northern half of the “Southern” suburbs and “Northern” suburbs of Cape Town, while the second trail targeted the southern half of the “Southern” suburbs. The main results expected from our experimental setting were expressed in terms of

*Pollution mapping and publishing* by (1) producing a pollution map with tagged locations of pollution thresholds using Google Maps based upon readings taken from all
three experimental trials and (2) proposing graphs of the levels of different pollutants to reveal their concentration.

*Readiness for field deployment* by measuring (1) the battery lifetime in both GRPS and ZigBee modes and (2) the packet loss in both modes.

### 3.2 Pollution Mapping and Publishing

To measure the levels of pollutants, we used a cloud representation where redder clouds represent higher pollution reading at that point. The pollution readings are recorded by the mote as a voltage level measured across the pollution sensor at that particular point. This is then used to calculate the resistance of the sensor, which is then used to calculate the ratio between the readings at that point against the calibration point. This ratio is between 0.5 and 1, with the resistance ratio decreasing in value as the pollution level increases, as described by the datasheet in Figure 7. Two types of clouds are used: those without circles representing the pollutant levels taken in Zigbee mode and the ones with circles within them which present the pollutant levels taken in GPRS mode. The readings were averaged at a particular point if multiple readings were taken at that geographic location and the time label considered was the one of the last reading taken at that point. This provided images that give an overview of the results by spotting general trends with regards to the sensors. Looking at the pollution map depicted by Figures 5 and 6, one should note that the sensor responds to the levels of the whole group of the gases, and so is a composite value of the various gas concentrations present. While this doesn’t allow for accurate measurement of the level of a particular gas, it does give an effective “neighborhood” which the various gas levels fall within, and thus an indication of the level of air pollution.

![Figure 5: Pollution Map (Second Day)](image-url)
To measure these approximate concentrations of each gas, we calculated the resistance ratio of the gas sensor (which is the ratio of the resistance of the sensor against the calibrated reading). Using the gas curves, we derived functions which related the different resistance ratios to gas concentration readings. We then used that function to plot the potential concentration for the various gases under consideration. The results reported by Figures 8-14 did not reveal a great deal of correlation between the two sensors. However, they were both within the same range usually separated by a few parts per million. This lack of agreement may be justified by the fact that (1) the readings were taken while the vehicle was moving around, and since they were not taken at the exact
same time, they were essentially taken at different locations (2) the general constant offset trend is due to the fact that the GPRS sensor had far fewer calibration readings than the Zigbee device. This is further exhibited by the volatility seen by this device against the Zigbee device’s readings. Using both map plots, it does seem to make sense that the Northern Suburbs of Cape Town which is more "polluted" than the Southern Suburbs, especially given the presence of an oil refinery in the area.

Figure 8: Ammonia

Figure 9: Ethanol
Figure 10: Carbon Dioxide

Figure 11: Ammonia
3.3 Readiness for Field Deployment

As depicted by Figure 15 and 16, the experiments conducted on the readiness of the sensors for field deployment revealed that the two sensors’ readings correlate after calibration, suggesting that multiple sensors such as these could be used in conjunction. As depicted by Figure 15 and in agreement with the datasheet, the GPRS module was not working after the battery dropped below 55%, causing the GPRS modem to shutdown. This is illustrative of the need for further prototyping and performance testing, as was the fact that the data wasn’t saved to that module’s SD card (the other module’s SD card
worked fine) in the first trial. In the second trial, there was a problem with the GPS module used with the GPRS mote, not allowing for locations of the readings to be recorded. However, by the third trial, the various issues were worked out, and the devices performed well.

The packet loss for the GPRS sensor of 10%, which is quite high, however this is in agreement with recent events in South Africa, where the mobile operators were fined heavily last year because 1 in 20 SMSs were not reaching their destination. This finding suggests moving to actually using GPRS as opposed to SMSs, due the exponentially lower cost of GPRS data links versus SMS messages and reliability mechanisms built into Internet protocols. However, the issue of availability of GPRS versus GSM in the target area must then be considered. The packet loss for the Zigbee sensor was also 10%. For the packet loss, Figure 17 shows where the packet loss occurred while Figure 18 summarizes the instances into hourly bins. The distribution of the dropped packets for the GPRS is quite widely spread, as is to be expected, while the Zigbee is concentrated at the beginning and one anomalous instance.

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**Figure 15: Battery Lifetime (Third Day)**

**Figure 16: Battery Lifetime (Third Day)**
4. Conclusion and Future Work

Building upon the need to monitor pollution in cities, this paper presents the main ideas behind a community sensor networking model aiming to launch environmental sensors into our daily life in order to build environmental maps and promote public participation in the fight against air pollution. Using an experimental air pollution monitoring Testbed in the city of Cape Town, we illustrate the use of the proposed community sensor networking model in terms of sensor readiness for field
deployment and air pollution recognition. Our experimental setting reveals that (1) pollutions map can be built using off-the-shelf sensor equipment (2) both Zigbee and GPRS can be used as information dissemination protocols for the sensed data (3) this can be done with low packet loss and (4) the experimental results may be published using web services such as Google Maps. However, there is room for further improvements in the way our experiments were conducted. These include better calibration of the sensors, opportunistic transmission in the presence of different types of gateways and the running of the experiments to evaluate the impact of daily climate variations and road traffic fluctuations on pollution.

**Literature**


