Low Power EMC Optimized Wireless Sensor Network for Air Pollution Monitoring System

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Abstract: Air pollution has significant repercussion on the concentrations of constituents in atmosphere leading to consequences like global warming and acid rain. Traditional air polluting monitoring methods are expensive and bulky, to overcome this disadvantage WSN (Wireless Sensor Network) has come into existence which has advantage of being small, easy to setup, inexpensive and provide real time monitoring of data. In this paper, modular wireless sensor architecture for pollution monitoring system that measures the level of carbon monoxide, particulate Matter, nitrogen-di-oxide and sulphur-di-oxide in environment and sends the measured data to server is proposed. The proposed system is designed for extremely low power operation which monitors the pollutants level and sends the data to server via GPRS and can be used in secured places like military and defence.

Keywords: *Wireless Sensor Network, Internet of Things, Media Access Control, Electro-Magnetic Compatibility, Low Drop Out regulator*

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I. INTRODUCTION

Air pollution is a common issue in developed and developing nations with Delhi being the 2nd largest polluted city in Asia. Air pollution is the presence of contagions or pollutant substances in the air that hamper with human health or welfare, and also has other harmful environmental effects. Air pollution monitoring is considered to be very complex task but it is very important in urban places.

Currently there are two methods for monitoring air pollution. One is non-automatic or passive sampling in which it uses simple equipment and does not provide real time data. Another method is automatic or online sampling in which sensors are used to monitor the data and send the data to central server on real time basis which involves wired or wireless systems to monitor the pollutants.

Traditional methods of monitoring includes mass spectroscopy (MS), gas chromatography (GC) and Fourier transform infrared instruments (FTIIs) which provides accurate data but has disadvantages of high cost, large size and time consuming. Hence wireless sensor network came into existence to overcome this advantage which has advantages of being small, inexpensive, easy to setup and enabling real time monitoring of data. Major disadvantage of wireless sensor network is its high power consumption during transmission and processing of data. One of the methods to reduce power consumption in a wireless sensor network is the usage of energy efficient sensors and selection of low power consumption microcontroller. Another method to reduce the power consumption in a wireless sensor network is to incorporate data compression algorithm.

II. LITERATURE SURVEY

Wireless sensor network technology is the emerging technology in the field of communication. Various methods to monitor air pollution and to operate the wireless sensor network on reduced power consumption were proposed. Design of energy aware air pollution monitoring system using WSN was proposed which mainly focuses on low power consumption by using low power strategies, hierarchical routing protocols and casing the motes to sleep during idle time [1]. A low power wireless sensor network for online ambient monitoring was proposed, This system uses Wi-Fi to monitor indoor air pollution which uses energy efficient sensors for low power operation gives us the conclusion that the system can operate on a single 3 V battery for up to 3 years [2]. A conceptual frame work for air pollution monitoring system for Bangalore urban city was proposed which gives us the details of monitoring air pollution on real time and spatial basis in Bangalore city [3]. The Government of Taiwan uses various methods to monitor air quality which has hazardous health effects. This method use MAC for monitoring air quality in Taiwan city [4]. A survey on data compression algorithm was proposed which gives the details of data compression method incorporated in a wireless sensor network for low power operation [5]. Air pollution detection based on head selection clustering and average method was proposed which mainly focus on longer sustain time period of sensor network, effective processing of collected information and less overhead in routing information between sensor nodes [6]. Huffman and Lempel-Ziv based data compression algorithm for wireless sensor network was proposed in 2013 which explains the efficiency of Huffman and Lempel-Ziv algorithm compared to different data compression algorithm to minimize the energy consumption in a wireless sensor network [7].

III. TECHNOLOGY USED

Modular architecture: Modular design is a design advent in which the system is divided into smaller parts called modules that can be independently created and designed and then can be used in different systems. A modular system is designed by functional partitioning into scalable, reusable modules.The beauty of this concept is that we can replace or add any component or module without affecting the rest of the system functionality.

The hardware consists of

- CPU and other communication components which remains the same. Plug-ins can be designed as per requirements.
- Any sensors can be added and customized.

Low power operation: Power optimization is the main challenge in the field of wireless communication. Hence the

wireless node which is operated by battery has to be optimized for longer life and durability.

There are two methods by which power can be optimized.

- Power optimization in hardware: A hardware component that consumes low power is selected and LDO (Low Drop Out regulator) is used which helps to reduce power consumption.
- Power optimization in software: Switching ON and OFF of hardware components according to requirement and can be optimized by task optimization.

The wireless modules are connected to AA battery. The battery depletion power is more and replacement of battery consumes lot of man power and money and hence power optimisation plays a very important role. The components are checked for power consumption and optimized eventually. The battery life time is 1500mAh. The aim is to provide a wireless sensor network for pollution monitoring system which lasts up to 2 years. Studies show that transmitting data is more power consuming that processing the data. Minimizing the size of data before transmitting in a wireless medium plays a very important role in reducing the power consumption. Hence a data compression algorithm is implemented for low power operation before transmitting the data to master.

EMC Optimization: Electromagnetic Compatibility is the ability of an equipment/ system to function in the intended environment without causing performance degradation due to electro-magnetic interference. All the products must comply with international EMC standards which have been developed to control and radiate emissions from electronic systems. There is lot of RF and EMI emissions in the field, if filter is not provided then system malfunctions and therefore to filter out the noise, the filters are very much necessary. The goal of EMC is the flawless operation, in an electromagnetic environment of different equipment which uses electromagnetic phenomena, and avoidance of any interference effect. The need for EMC standards is

- EMC standards are required for a trouble free co-existence and to ensure the satisfactory operation of system.
- They are useful to provide compatibility between electrical, electronic, computer, control and other systems.
- Standards are required as manufacturer-user interaction and user's knowledge on EMI are limited.
- They are required for establishing harmonized standards to reduce international trade barriers and to improve product reliability and life of product.

IV. IV.METHADOLOGY

The proposed system is able to measure the following gases in the environment.

- **Carbon Monoxide (CO):** CO is a plain, flavourless, unscented, non-irritating gas produced when experts of carbon, such as, fuel or woods are burned. Common sources of human exposure to CO gas include smoke inhalation from fires automobile exhaustion, cigarette smoke. It causes respiratory problems.
- **Sulpher-Di-Oxide (SO2):** SO2 is a pale gas, detectable by different odour and flavour. It is due to fossil fuels burning. In high concentrations may cause respiratory problems, in sensitive groups, like asthmatics. It contributes to acid rains.
- **Nitrogen-Di-Oxide (NO2):** NO2 is a corrosive and oxidizing reddish-orange-brown gas with a characteristic pungent odour easily noticeable for its smell, very acidic and highly oxidant. It is produced because of fossil fuels burning. It also contributes to acid rain.
- **Particulate Matter (PM):** Dust and other soot particles in the environment.

Sensors selection was based on its power consumption criteria. The below table show the specifications of components.

- CO

Parameters	Values
Part number	TGS2441
Measurement range	0 to 1000ppm
Sensitivity	0.13 ~ 0.31 (Change ratio of Rs)
Power consumption	20mA

- NO2

Parameters	Values
Part number	MiCS 2710
Measurement range	0.05 ~ 5ppm
Sensitivity	6 ~ 100
Power consumption	26mA

- SO2

Parameters	Values
Part number	CXT-DM
Measurement range	0 – 20 ppm
Accuracy	±2% FS
Power consumption	20mA

- Particulate Matter sensor

Parameters	Values
Part number	GP2Y1010AU0F
Measurement range	0 ~ 500 ppm
Accuracy	
Sensitivity	Typical : 0.1mg/m³
Current consumption	20mA

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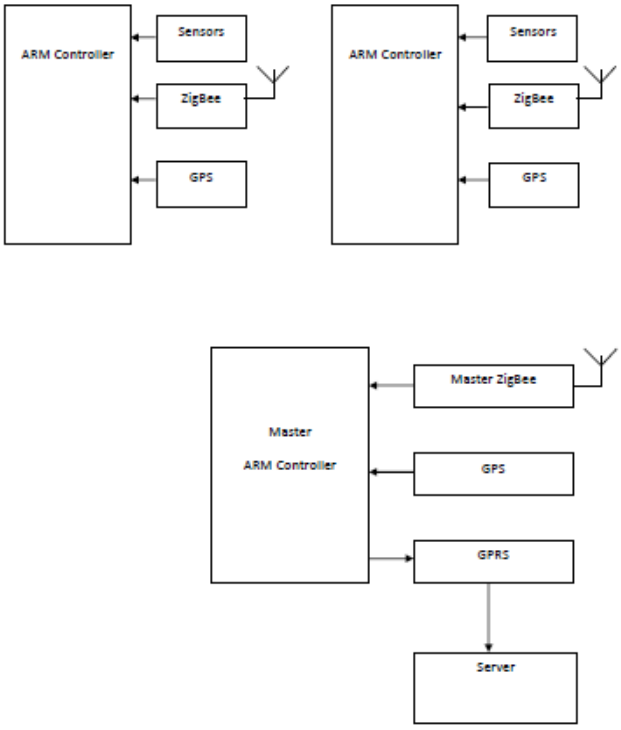
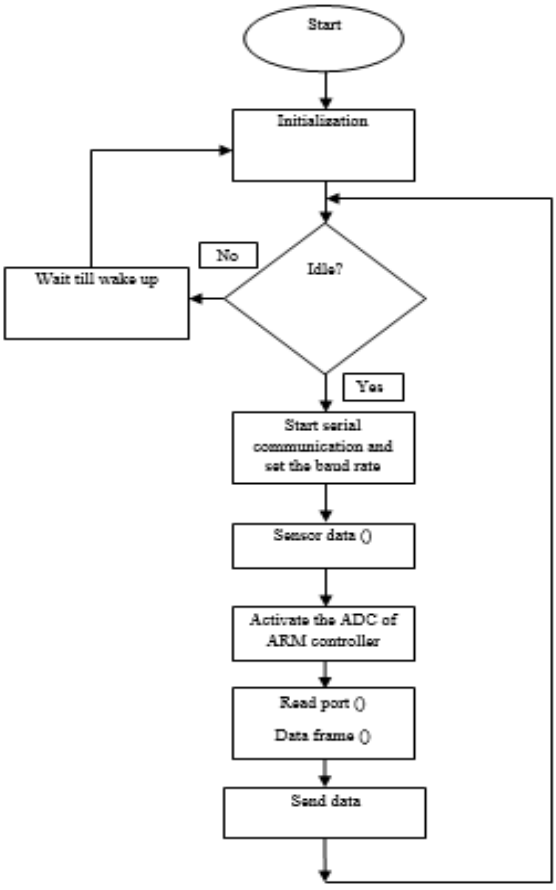
BLOCK DIAGRAM:

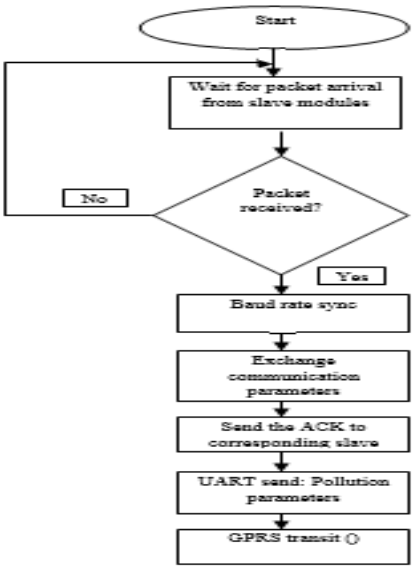


Low power ARM controller was selected based on Industry – Standard Bench Marks for Embedded Systems [8]. EEMBC, an industry alliance, develops benchmarks to help the system designers to select the optimum processors and understand the performance and its energy characteristics. ARM processor is the core of the air pollution monitoring system which is low power and high performance device most commonly used in wireless sensor networking industries. The ARM processor LPC2378 is based on 16-bit or 32-bit ARM 7 TDMI – S CPU. The manufacturers of LPC2378 are NXP semiconductors.

Individual slave module was tested for sensing the temperature, CO, SO2, NO2 gases by using embedded C language. Individual Slave module consists of gas sensors, temperature sensor, ZigBee, ARM controller with inbuilt ADC and the master module consists of ARM controller, GPS, ZigBee and a separate GPRS for sending the data to server. Master module and GPRS is connected to power source and individual slave modules are connected to AA battery which gives the capacity of 1500Ah. The Main intension in selecting AA battery is its availability and replacing these batteries in rural areas is much easier and also its cost efficient compared to other batteries like lithium ion battery. Individual Slaves modules were ready for sensing the data and sending the data to master module via ZigBee and master to the server. The sensed data was observed in server on a platform eclipse indigo using the compiler isense. Below show the flowchart of the slave module.



Every slave module is recognized by its unique MAC address to know from which slave module the data is being sent to the master. A Media Access Control address (MAC address) is a unique identifier assigned to network interfaces for communications on physical network segment. MAC addresses are used as a network address for most IEEE 802 network technologies, included Ethernet and Wi-Fi.Below shows the flowchart of the master module.



V. LOW POWER OPERATION

Low power operation has been implemented to the pollution monitoring system for a battery life time of more than 2

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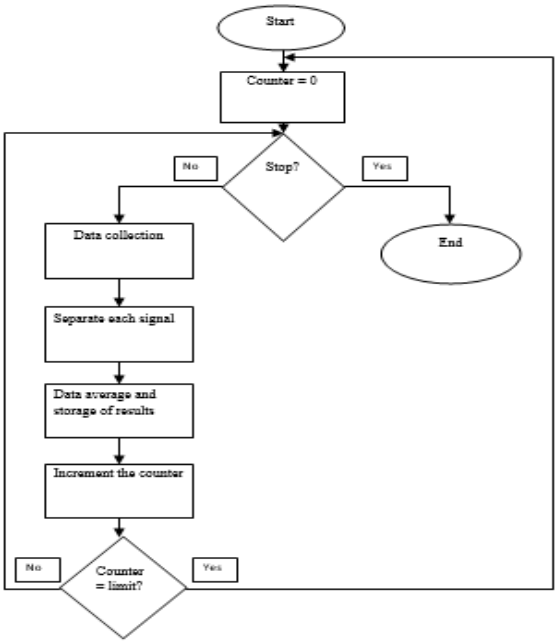
years. Power consumption is a critical issue for a wireless sensor network. The overall energy in a Wireless sensor node is consumed in three different processes. They are: Data processing, sensing the environment data, and the energy consumed for data processing. The energy consumption is reduced in the process of data transmission of the sensed data to the master. One of the goals of the WSNs designers is to reduce the number of packets, as well their size that is sent over the network, by using data compression techniques.

Gzip is a file format and software application used for file compression and decompression. Mainly used if the file is a text file. Gzip locates similar strings within a text file and replaces those strings temporarily to make the overall file size smaller. Since Gzip compresses common strings, this can reduce the size of file and style by up to 70%. The main reason it is important because it reduces the time it takes for transfer the page and files which ultimately reduce the time and power it consumes. Gzip is based on the deflate algorithm, which is a combination of LZ77 and Huffman coding.

Power reduction used in proposed method: RF consumes more power of all hardware devices. Sending data in ZigBee varies from 20kbps in 868 MHz maximum. We can send data at 20 kbps but it has 2.4 GHz therefore the data rate tested was 250kbps, but my data rate is 60bytes and consumes less power of transmission power and reception power. Hence the power can be optimised.

Packet size = Packet transmission time × Bit rate.

ZigBee employs AES algorithm mode to provide protection against attack. IEEE 802.15.4 provides message confidentiality for ZigBee via MAC layer, which runs AES 16-octet block and key size 128-bit. The analyst has to try 2128 combination key to detect the correct key, or to do 264 steps of operation where the time complexity to break it can be computed as O (log264). So, a 64 bit encryption string is always worse than a 128-bit, 192-bit or 256-bit key. But the chances of hacking are anyway lesser for a 64-bit key as well. The DES 64-bit algorithm was employed instead of AES 128-bit algorithm for low power operation. A cryptographic key and algorithm are applied simultaneously to the block of data rather than one bit at a time. To encrypt the message DES groups the messages it into 64 blocks. Flow chart of data averaging for obtained interval of time is shown below.



VI. RESULTS & SIMULATIONS

After system testing, the system was kept under observation in the field for a span of one week. The system was operated in the field for sensing the data and sending the sensed data to the master and master to the serial monitor via GPRS. The data observed in serial monitor was retrieved to the excel sheet. The below figure-1 show the air pollutant data which is sensed by slave module and sent to master module and was retrieved to excel sheet from serial monitor.

Identity	CO	NO2	SO2	PM
	µg/m3	µg/m3	µg/m3	µg/m3
2/23/2015 0:00	1.55	20.49	10.39	37.31
2/23/2015 1:00	1.36	20.14	9.49	23.65
2/23/2014 2:00	1.47	21.39	9.46	16.83
2/23/2015 3:00	1.71	20.95	10.12	18.41
2/23/2015 4:00	1.87	20.64	11.24	11.7
2/23/2015 5:00	1.33	21.44	11.49	61.8
2/23/2015 6:00	1.78	20.57	11.78	57.28
2/23/2015 7:00	1.98	20.95	11.39	33.64
2/23/2015 8:00	1.89	20.55	9.81	39.86
2/23/2015 9:00	1.75	20.8	9.97	51.44
2/23/2015 10:00	1.82	20.85	9.41	35.15
2/23/2015 11:00	1.81	20.74	9.55	74.77
2/23/2015 12:00	1.56	20.66	10.38	68.02
2/23/2015 13:00	1.73	21.07	10.49	45.56
2/23/2015 14:00	1.41	20.52	10.47	38.21
2/23/2015 15:00	1.7	20.48	10.65	43.94
2/23/2015 16:00	1.28	21.04	10.39	42.35
2/23/2015 17:00	1.64	21	10.38	57.94
2/23/2015 18:00	1.74	21.42	11.17	57.31
2/23/2015 19:00	1.71	20.61	13.02	42.7
2/23/2015 20:00	1.93	20.46	9.29	53.69
2/23/2015 21:00	1.83	21.06	9.71	61.82
2/23/2015 22:00	1.91	21.12	10.21	59.72
2/23/2015 23:00	1.39	20.8	9.6	62.94
2/24/2015 0:00	1.14	20.47	10.9	46.6

Figure-1: Observed Pollution Data

The low power operation in an air pollution monitoring system which is AA battery operated was obtained for 2years. The calculations of power is as shown in the below figure-2.

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Phase I								
Modules	I(A)	Seconds	Hours	Current/ hour(Ah)	Current/Year (Ah)	Years	Months	Days
GPS	0.05	3	0.00083	0.0000417				
pm Sen	0.01	3	0.00083	0.00001668				
CO Sen	0.01	3	0.00083	0.00001668				
SO_2 Sen	0.01	3	0.00083	0.00001668				
µC	0.06	7	0.00195	0.00011676				
RF	0.05	7	0.00195	0.0000973				
NO2	0.026	3	0.00083	0.000021684				
				0.000527484	2.85875984	1.04575	12.549	376.469
Phase II								
GPS	0.05	3	0.00083	0.0000417				
pm Sen	0.01	3	0.00083	0.00001668				
CO Sen	0.01	3	0.00083	0.00001668				
SO_2 Sen	0.05	3	0.00083	0.0000417				
µC	0.045	7	0.00195	0.00008757				
RF	0.01	7	0.00195	0.00005892				
NO2	0.026	3	0.00083	0.000021684				
				0.000264984	2.32082184	1.29265	15.5117	465.352
Phase III								
GPS	0.05	2	0.00056	0.0000278				
pm Sen	0.01	2	0.00056	0.00001112				
CO Sen	0.003	2	0.00056	0.000001668				
SO_2 Sen	0.05	2	0.00056	0.0000278				
µC	0.037	7	0.00195	0.000072002				
RF	0.01	5	0.00139	0.0000139				
NO2	0.026	2	0.00056	0.000014456				
				0.000168746	1.47821496	2.02947	24.3537	730.611

Figure-2: Power Calculations

EMC optimization was carried out and system was tested for operating in the field with Electro-Magnetic compatibility. The figure-3&4 give us the details of EMC optimization of air pollution monitoring system and the filters which were added to the system for EMC.

Qualification Test Reports

EMI/EMC Reports of WSN for Pollution Monitoring system

EMC TEST CENTRE

No.9030/EMC/QA/INT/D&E/SS/NS Dtd.18/02/2015

Sub : EMI/EMC test on WSN FOR POLLUTION MONITERING SYSTEM
Ref : EMC Test Request No.2780 / dated 20/02/2015 and 2812 Dated 24/02/2015 .

With reference to the above subject, EMI/EMC tests were conducted on WSN FOR POLLUTION MONITERING SYSTEM

1.0 Applicable Standard: MIL- STD- 461E

2.0 Susceptibility Criterion: During the susceptibility test, the EUT was given input signal of 5Vp-p/4.5KHz and the output observed was 10.5V/4.5KHz.

3.0 Tests Conducted & Summary:

Sl No.	Tests	Measurement Conducted	Remarks
1.	CE102 (10KHz to 10MHz)	Conducted on phase1, phase2, and phase3:	Meets the specification. NOTE: The above results were achieved after adding 15mH CM choke on the power line.
2.	RE101 (30Hz to 100KHz)	Antenna at Front bottom, Right side, Left top, Back top :	Meets the spec.
3.	RE102 (10kHz – 1GHz)	V-Pol : (10kHz – 1GHz) H-pol: (30MHz – 1GHz)	Meets the Spec. Meets the Spec.
4.	CS 101 (30Hz to 150KHz)	Conducted on phase1, phase2, and phase3:	Meets the specification. Note: The test was done with -24dBm output power level, due to the limitation in the test setup. During susceptibility test, no degradation in the performance of the EUT was observed.
5.	CS 114 (Curve#2) (10KHz to 200MHz)	Injected on power cable and individual high lines of power cable.	Meets the specification. During susceptibility test, no degradation in the performance of the EUT was observed.

Page 1

Figure-3: EMC Report

Figure-4:Contd... EMC Report

VII. CONCLUSION AND FUTURE WORK

A wireless sensor network for air pollution monitoring system was successfully established in the field and the air pollution data was obtained as shown in figure 1. The sensors used are low cost sensors and provide us low resolution data but that data is enough to provide warning to public. The major issue with air pollution monitoring system is its life time. The low power wireless sensor network for air pollution monitoring system is very important in current day scenario and hence low power operation was implemented to the system for its real time monitoring with the battery life time of two years. The system was successfully calculated to operate in the field for two years. For a system to operate in the environment with lot of RF and EMI and other noises like electromagnetic spark plug emission, the system has to be added with filters like CM choke, and capacitance filters etc.

For a battery lifetime of more than 2years solar cells can be implemented. Use of the pollution monitoring system for IOT where it will land up every data in cloud can be implemented. The advantages of cloud computing are low cost, universal access, economical and low energy consumption

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