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An Energy-Efficient Hybrid Model With Adaptive Sampling Technique For Air Quality Monitoring System In The Cremation Center

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ABSTRACT

In the recent past internet of things (IoT) has become promising technology due which it has grabbed the attention of the research community, industry, and end-user**.** Energy management is one of the massive constraints with an IoT sensor node because sensor nodes are often battery operated. In India, cremation centers are located within the city premises, due to the continuous emission of harmful gases such as carbon monoxide (CO), ammonia (NH3), it will deteriorate the people's health those who are closely located. In this paper, we have designed an energy-efficient Mobile Air Quality Monitoring System (MAQMS) and installed it in the cremation center in Hyderabad, India. MAQMS can measure harmful pollutants released into the environment during the cremation process. The proposed system measures the five different gases, such as carbon monoxide (CO), particulate matter 2.5, particulate matter 10, ammonia (NH3), and nitrogen dioxide (NO2). To reduce the power consumption of MAQMS, we proposed an algorithm that allows MAQMS to operate in a hybrid model that is a combination of two modes, namely hibernation and active mode. For every one minute, we allowed the system to switch between a hibernation mode and active mode with adaptive sampling to ensure data quality with efficient power consumption. The experimental results show that the power consumption by MAQMS per day before applying the hybrid model is 613.72A, whereas after applying the hybrid model, power consumption has a dropdown to 289.58A.

Keywords: IoT, air quality, sensor, hybrid mode, energy efficiency

I. IOT INTRODUCTION

The main objective of IoT is to connect things such as a smartwatch, home appliances, smart sensors, and surveillance cameras to the internet. A typical IoT system comprises of sensing subsystem, processing subsystem, communication subsystem, and power supply. Often all these devices are battery-operated and consume more power henceforth energy efficiency plays a very vital role in the implementation of IoT. There are a lot of techniques in the literature to reduce power consumption, thus opting for appropriate energy management system techniques will help to increase the lifetime of the overall system.

II. A RELATED WORK

Abdul [**1**] proposed taxonomy for major energy-saving techniques in the IoT. The proposed taxonomy divides energy saving schemes into nine categories. Anastasi et.al [**2**] author describes the sensing subsystem consumes less power compared to the processing subsystem, and the processing subsystem consumes less power compared to the communication subsystem. Energy efficiency techniques such as transmit data reduction, transceiver optimization, energy-aware data routing, and protocol overhead reduction will help to reduce communication subsystem energy consumption. [**3, 4, 5]** Energy consumed by sensor depends on the mode in which it's being operated such as active, idle, and sleep. In the sleep state, both sensing subsystems and communication switched off, whereas processing subsystems remain on. In [**6**] lifetime of the sensor is estimated depending upon its energy consumption. In [7], to reduce the power consumption of the IoT node, sleep and wakeup are used. In [8] system is designed to monitor the wetness of soil in the agriculture field. In the proposed system, the soil moisture sensor is interfaced with Node MCU, and node MCU is operated in deep sleep mode. Data is transferred every one hour to the cloud. It's observed 83% powered reduced for one hour in deep sleep when compared to always-on mode. Every one-hour soil moisture sensor will wake up for 10 seconds to measure the wetness of the soil and send the data cloud server. In [9], when the processing subsystem operates in deep sleep mode, there exists a tradeoff between data quality and battery life. Always on the state allow the sensor to send data more frequently, but it drains the battery very quickly. In deep sleep mode, sensors don't measure values, and henceforth, the lifetime of the battery is increased. In [10], two schemes, namely early data transmission (EDT) and early sleep (ES) schemes are proposed to reduce latency and energy consumption in IoT. ES scheme ensures non-destined devices go to sleep in the early state by decoding and validating address bit by bit. In [11], described when the processing subsystem operates in deep sleep mode, it improves battery life from days to years. In [12] describes to design energy-efficient protocols, sleep mode plays a vital role. In [13], different energy-saving techniques were discussed, based on network type, applications we can opt for the best technique.

III. PROPOSED METHOD

In the proposed system, we designed an energy-efficient Mobile Air Quality Monitoring System (MAQMS) using IoT to measure harmful gases released into the environment from the cremation center. In MAQMS sensing subsystem (SS) comprises three sensors MQ7, MQ 135, and dust sensor to can measure gases such as carbon monoxide (CO), particulate matter 2.5, and particulate matter 10, ammonia (NH3), and nitrogen dioxide (NO2). The processing subsystem (PS) consists of ESP 32 that operates in two different modes, active and hibernation mode. When the PS operates in hibernation mode, then the only real-time clock is operational, and remaining all parts in the chip are powered off. We tested in the laboratory when the PS operates in active mode, ESP 32 consumes 86 mA, but when it operates in hibernation mode, power consumption drops from 86mA to ~2.5µA. [9] Describes a trade-off between data quality and battery life. The system is allowed to operate in a deep sleep mode, in this mode, SS is power off and doesn't acquire any data to increases battery life. When the system is in active mode, SS and PS are always on and continuous senses data, and with the help of CS uploads to the server henceforth, thus it will reduce battery life. The proposed model is a hybrid of active mode and hibernation mode that ensure data quality with efficient power consumption. In the proposed model, we design a system such that the processing subsystem is on for 1 minute and goes to hibernation mode for 1 minute and the process will continue so that we can acquire data in a regular interval of time and ensure quality data besides that we reduce power consumption. When the SS is in the active mode, we considered adaptive sampling, in which on state communication subsystem will upload data only when the sensed value is greater than the threshold of the sensor so that we can save the power of the communication subsystem. The system is designed to measure harmful gases released from the cremation center, henceforth, we enable the system from 7 AM to 7 PM, and the system goes to complete hibernation mode from 7 PM to 7 AM because the cremation center will be closed. To monitor the time stamp, we have configured on-chip RTC.

3.1 IoT Subsystems:The entire system power consumption is calculated in different stages. We calculated the power consumed by the sensing subsystem, processing subsystem, and communication subsystem.

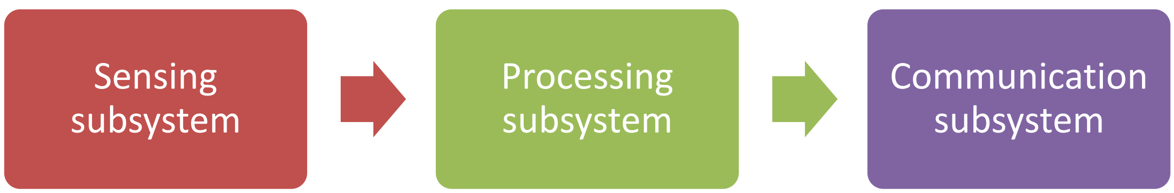

Fig 1:IoT Subsystems

$$TPC=\sum PSS+PPS+PCS \quad (1)$$

TPC = Total power consumed by system
PSS = Power consumed by sensing subsystem
PPS = Power consumed by processing subsystem
PCS = Power consumed by Communication subsystem

3.2 Block Diagram of proposed system:ESP32 comprises on-chip 12-bit 18 channel ADC, RTC and microprocessor, SRAM, Wi-Fi, and onboard communication protocols, namely I2C, SPI, CAN, and UART to interface sensors. In the proposed design, the sensing subsystem comprises three sensors, namely MQ7, MQ135, and dust sensors are interfaced with Channel 0, 1, 2 respectively to, measure harmful gases released in the environment during the cremation process. Node is installed in the cremation center to measure gases. To save the power, we operate the node in hybrid mode from 7 AM to 7 PM, and the node will go to complete hibernation mode from 7 PM to 7 AM because there is no emission in the cremation center during this period.

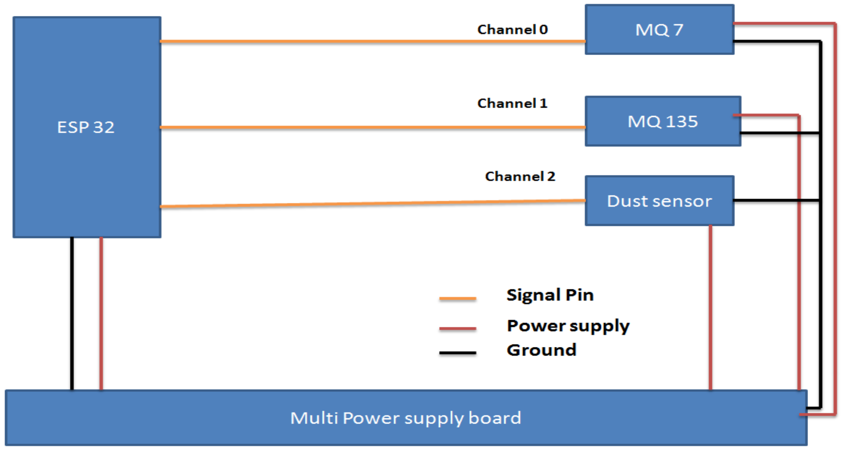

Fig 2: Block diagram of proposed system

2.3Processing subsystem operating modes:Power consumption of the processing subsystem that is ESP 32 depends on the mode in which it's being operated. ESP 32 can operate in five different modes such as active, modem sleep, light sleep, deep sleep, and hibernation mode. From the table mention below, we can see that each mode has a distinct power saving capability. Hibernation mode is the most power-efficient compare to all the other modes in ESP32. In this mode, except RTC timer remaining all, digital peripherals, CPU core, memory, ULP coprocessor, and Wi-Fi are power off. RTC timer is responsible for waking up the entire chip from hibernation mode.

Table 1: Processing subsystem operating modes with power consumption

Modes	Peripherals	Wi-Fi	ESP 32 Core	RTC	UPL coprocessor	Power consumption
Active	√	√	√	√	√	160-260 mA
Modern sleep	√	×	√	√	√	3-20 mA
Light sleep	×	×	Pause	√	√	0.8 mA
Deep sleep	×	×	×	√	√	10 µA
Hibernation	×	×	×	√	×	2.5 µA

Note x= Not active, √ = Active

IV. RESULTS AND DISCUSSIONS

4.1 Hibernation mode: As mention above, in hibernation mode, only the RTC timer is powered on, and the remaining parts of the system are powered off. Table mention illustrates the power

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consumption of the system when operated in hibernation mode. In this mode sensing subsystem, processing subsystem, a communication subsystem is powered off.

Table 2: Power consumed in hibernation mode

Duration	SS	PS	CS	ADC	RTC	Total power consumed in hibernation mode
1 Min	×	×	×	×	2.5 µA	2.5 µA
1Hour	×	×	×	×	150 µA	150 µA
1 Day	×	×	×	×	3600 µA	3600 µA

4.2 Active Mode:The table below illustrates the power consumption of active mode. We measured power consumed by individual subsystems and later measured total power consumed by the complete system, which is the sum of the individual subsystem.

Table 3: Power consumed in active mode

Duration	SS	PS	CS	ADC	RTC	Total power consumed in active mode
1 Min	0.239 A	0.06 A	0.092 A	0.009 A	0.0002 A	0.4262A
1Hour	14.34 A	5.16 A	5.52 A	0.54 A	0.012 A	25.527A
1 Day	344.16A	123.84 A	132.4 A	12.96 A	0.288 A	613.72A

C) Power consumed in hybrid mode:

Proposed system saves the power in three different stages

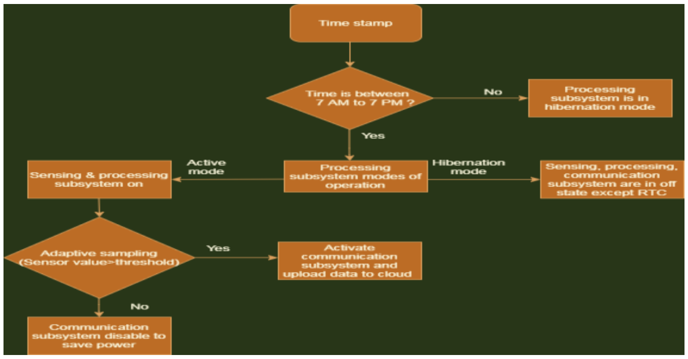

Fig 3: Flow chat of proposed hybrid model

Stage 1: The proposed system works in hybrid mode from 7:00 AM to 7:00 PM, and it will go to complete hibernation mode from 7:00 PM to 7: AM because there is no gas emission from the cremation center during this period.

Stage 2: System switches alternative between an active mode and hibernation mode. In an active mode, sensors will acquire information about pollutants for 1 min and goes to hibernation mode for 1 min. In this way, we ensure data quality with reduced power consumption.

Stage 3: From stage two when the system is in active mode, we acquire information about pollutants. However, we will upload data to the cloud server only then sensors value crosses the threshold range. This is called adaptive sampling. With the help of adaptive sampling, we can save the power of the communication subsystem.

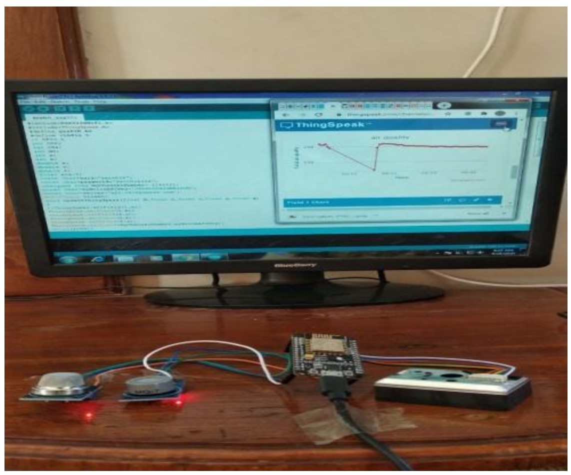

Fig 4: Experimental setup in the laboratory

Table 4: Power consumed in proposed hybrid mode

Duratic n	SS	PS	CS	ADC	RTC	Total power consumed in hyb mode
1 Min	0.119 A	0.043 A	0.021 A	0.05 A	0.001 A	0.1881A
1Hour	7.14 A	2.58 A	2.1 A	0.30 A	0.006 A	12.12A
1 Day	172.8 A	61.92 A	48.24 A	7.2 A	0.144 A	289.58A

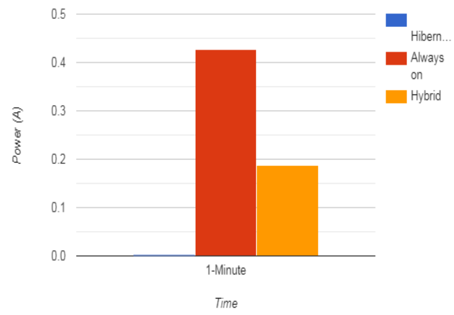

Fig 5: Power occupied by different operating modes in 1 minute

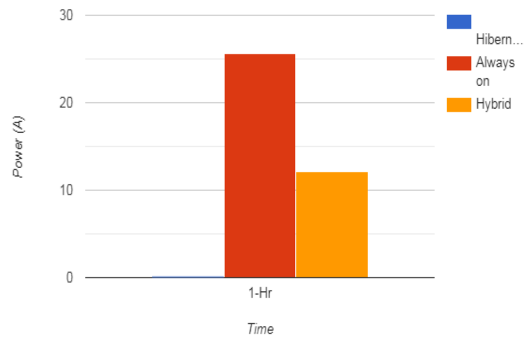

Fig 6: Power occupied by different operating modes in 1 hour

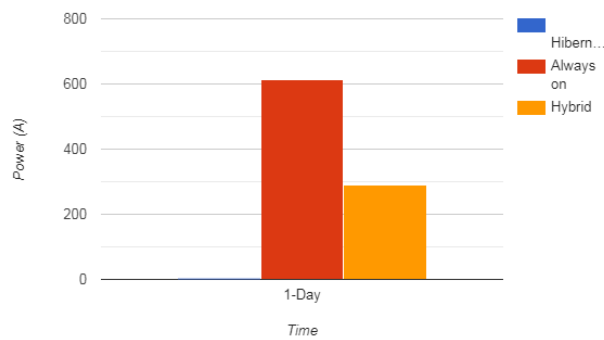

Fig 7: Power occupied by different operating modes in 1 day

From the graph shown below, we can see the concentration of gas emitted into the environment during the cremation process. We have measured the concentration of Carbon monoxide (CO), Particulate matter 2.5, Particulate matter 10, ammonia (NH3), and nitrogen dioxide (NO2).

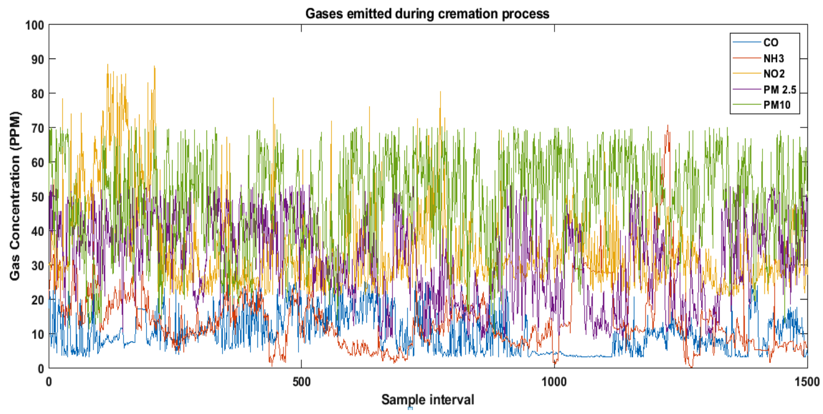

Fig 8: Concentration of different gases emitted during cremation process

The average current consumed by ESP 32 in active mode is 115 mA

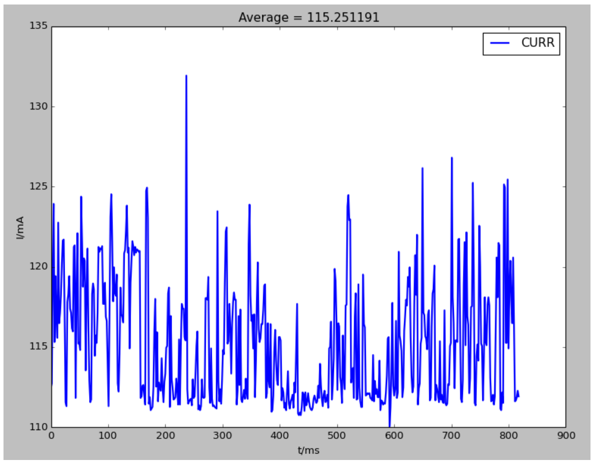

Fig 9: Average power consumed by ESP 32 in active mode

The Average current consumed by ESP 32 in hibernation mode with RTC as the wake-up source is 6μA

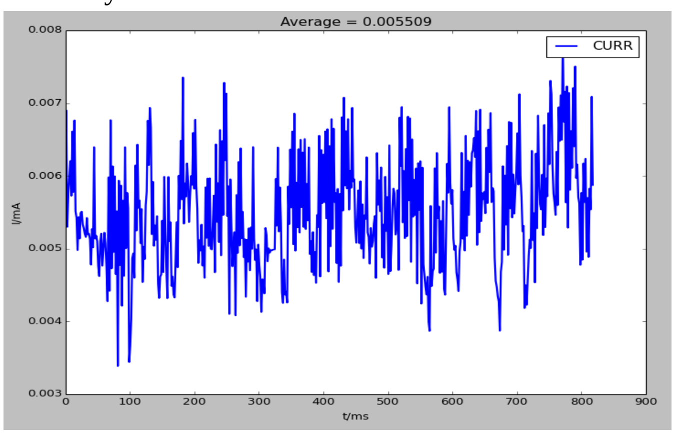

Fig 10: Average power consumed by ESP 32 in hibernation mode

In hybrid mode, ESP 32 performs data acquisition periodically 30 per minute. In the below graph, spikes reflect an instance of current when ESP 32 wakes up for hibernation mode

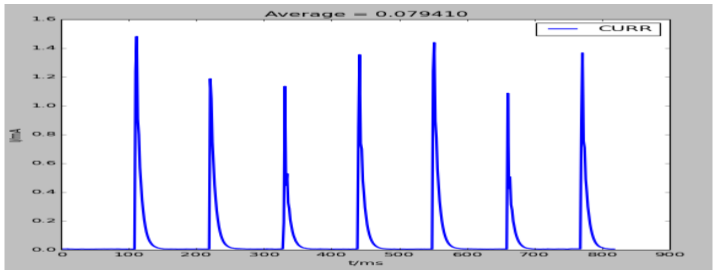

Fig 11: Average power consumed by ESP 32 when acquiringdata periodically (30samples per minute)

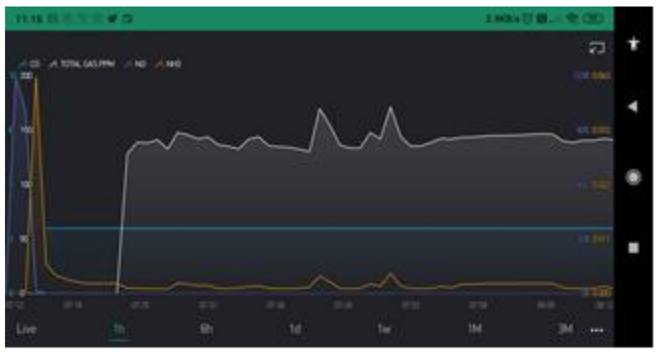

Figure 12:Output of air quality index in smart phone

V. CONCLUSION

In this paper, we designed a low-cost Mobile Air Quality Monitoring System (MAQMS) to measure the concentration of pollutants released in the air during the cremation process. We have also investigated energy consumed by individual subsystems in the proposed design that is the sensing subsystem, processing subsystem, and communication subsystem. To reduce the power consumption of MAQMS, we proposed an algorithm that allows MAQMS to operate in a hybrid model that is a combination of two modes, namely hibernation and active mode. For every one minute, we allowed the system to switch between a hibernation mode and active mode with adaptive sampling to ensure data quality with efficient power consumption. The proposed hybrid model will save energy consumed by MAQMS in three different stages. The experimental results show that the power consumption by MAQMS per day before applying the hybrid model is 613.72A, whereas after applying the hybrid model, power consumption has a dropdown to 289.58A. Henceforth from the experimental results, we can say that after applying the hybrid model to IoT node every day, 324.12A current we have saved.

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