Environmental Monitoring Using IOT

SYSTEM ANALYSIS

1.Air quality measurements standards

The measurement of air quality is carried out by state services based on standards acceptable levels of various substances in the air. Polish and EU standards limit the usual average levels of these pollutants.

Polish standard[26] defines maximum levels for dust pollution for two sizes: PM2.5 and PM10. PM2.5 is the concentration of particulate matter with an aerodynamic diameter of grains to 2.5 microns, and PM10 – to 10 microns. Acceptable levels of dust concentrations are determined for the average daily (PM10, the permissible level is 50 µg/m3), or an average annual (PM2.5, the permissible level is 25 µg/m3). The standard [26] was defined two additional levels of pollution (only for PM10):

- the level of informing the public (value - 200 µg/m3)

- the alarm level (300 µg/m3).

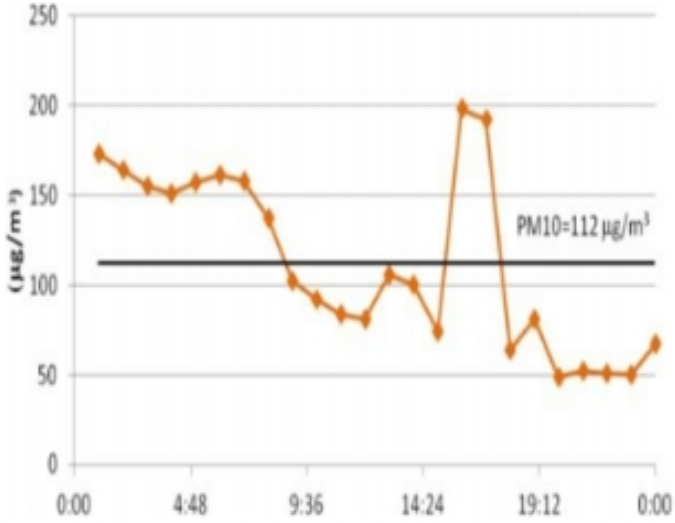

Fig. 2. The results of the daily measurement of the dust concentration (PM10; Dietla str., Krakow, Poland; March 18, 2016) with the marked daily average value (Source: [27])

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Both of these levels are defined in the standard for the average daily. Short-term increases in the level of pollution do not therefore constitute formal causes for the alarms (Fig. 2).

Such information may, however, be useful in the choice time and places of jogging or resting by citizens. For example, afternoon jogging would be better start after 18 and even better after 20 in the neighbourhood of the measuring station with the data from Fig. 2.

The concentration at this time was four times less than 16-17 hours.

2 .Inexpensive environmental monitoringsystem architecture

Inexpensive Environmental Monitoring system consistsof two basic components (Fig. 3):

- Mobile measuring stations,
- Server-side software.

Many mobile measuring stations, placed on the public transport vehicles (buses, taxi) or private (volunteers) during motion collect data on theconcentration of dust in the air. They used algorithms to optimize energy consumption and make sense of measurement and act as IoT agents.

Measuring stations transfer the data to the server ina situation where they will in the field of public WiFi network (e.g. accessible to the public in buses or other free Hot Spots located in different places of the city).

This solution reduces the operating costs of the system.In addition, the algorithms of transfer the measurement data to the server optimize energy consumption andtransmission time.

On the server side are implemented three basicfeatures:

- Mobile measuring stations (IoT agents) registration,
- Measurement data acquisition,
- Data presentation in various forms, layouts and profiles.

Server-side part of the system uses:

- HTTP server (Apache)
- PHP parser,
- database server (MySQL)
- external services (Google Maps)
- dedicated software (HTML, CSS, JavaScript, PHP).

The software has been developed using the responsive web design (RWD) approach and model-view-controller (MVC) architecture.

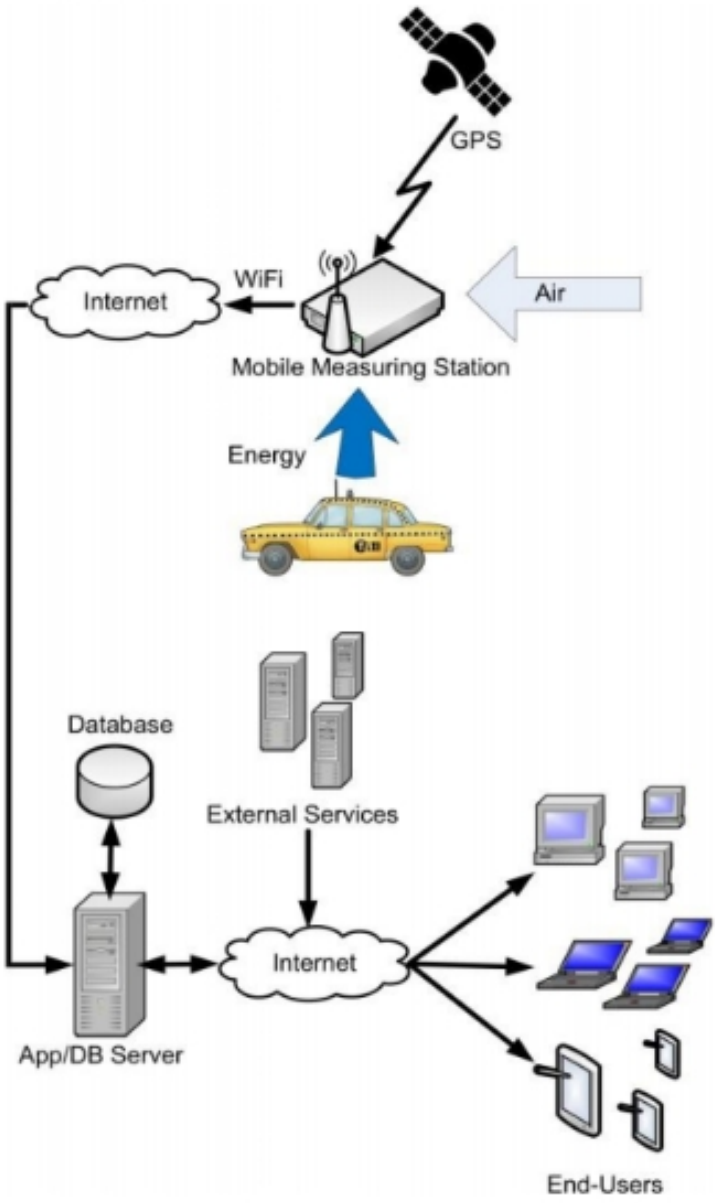

Fig . 3 . Architecture of the Inexpensive Environmental Monitoring System.

3.The moving IoT agent for dustconcentration measurements

The measuring station, which also acts as IoT agent, is designed in the compact way to fulfil the mobility requirements.

The overall architecture of the station is shown in Fig. 4.

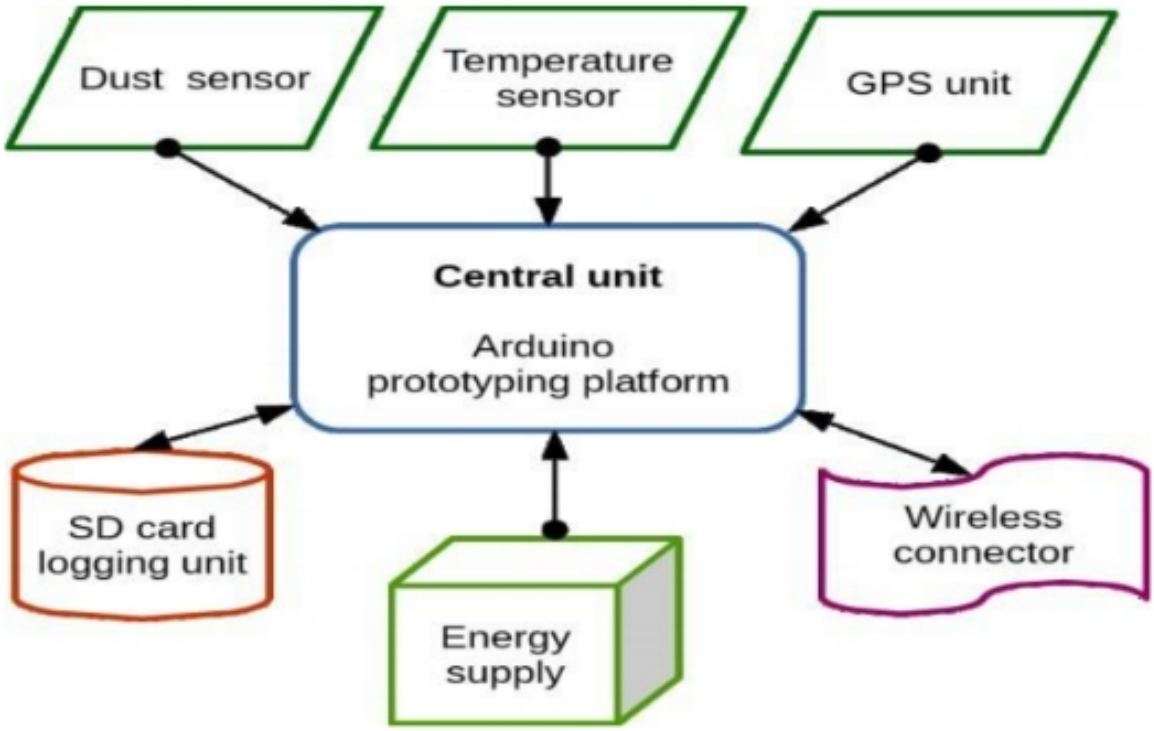

Fig . 4 . Architecture of the moving measuring station of dust concentration.

Station consists of the few sensors. The main one is the dust sensor for measuring the dust concentration, which gives a good indication of the air quality in an environment. However due to the specific way of dust sensor automatic measurement, this values cannot be assumed as reference values for dust concentration.

The other two sensors are: GPS for determining the position and temperature sensor for acquire working temperature. The range of working temperatures is important due to the dust sensor operation temperatures which are from -10 ºC to +65 ºC.

The heart of the IoT agent is the Arduino prototyping platform with Atmega chipset onboard. Arduino platform allows for programming all components together and act as single IoT agent. The measurement data is written to SD memory card for later transmission. In the designed system the WiFi module connected to the Arduino board acts as wireless connector. Wiring of the designed measurement station is shown in Fig. 5.

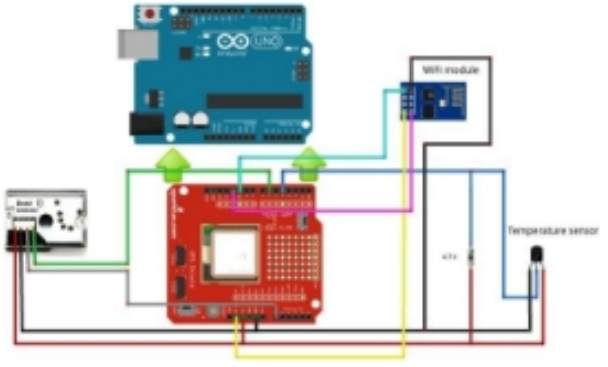

Fig. 5. Wiring of the dust measuring IoT agent.

On the top of Arduino Uno board the GPS shield is set. This shield is also equipped in SD card slot and additionally allows for transparent wire connection of external devices to Arduino board.

All other devices of an IoT agent i.e. dust sensor, temperature sensor and WiFi module are

10000 mAh capacity. That allows for approximately 6 hours measurement and communication session.

The hardware parameters of an IoT mobile dust level measuring station are shown in Table 1. Total cost of the station with additional hardware (cables, resistor, and casing) is about 125 €.

The agent performs measurements according to flowchart shown in Fig. 6. The series of measured data are averaged (10 measurements of dust level and temperature per second) and the averaged value is written to the file. That was assumed, that with allowed speed limit in the cities in Europe which is 50 km/h the vehicle changes its position by the 13.8 m during one second.

Table 1. Hardware parameters of IoT mobile dust concentration measuring station.

Hardware element	Description
Arduino programmable board	Arduino Uno board which is used as a main platform for sensors and dedicated agent software. Maximum current consumption is 46.5 mA with supplying voltage equals to 5V. Price 25€
Optical Dust Sensor	The sensor GP2Y1010AU0F has a very low current consumption (20mA maximum), supplying voltage up to 7V of direct current. The output of the sensors is an analogue voltage proportional to the measured dust density, with a sensitivity of 0.5V/0.1mg/m3. Price 14€
WiFi module	Wireless ESP8266 module, WiFi 802.11 b/g/n, working frequency 2.4 GHz, PCB antenna, current consumption 140 mA during transmission. Price 3€
GPS and SD card shield	The shield is SparkFun GPS Logger Shield - GPS GP3906-TLP with SD Card slot. It allows for GPS data recording and storing data on SD Card. Current consumption is 30 mA. Price 50€
Power bank	Polymos 10 AIR - 10000mAh power bank. Output current 2.1 A. Price 25€

However according to the [28] average speed varies from 19 to 35 km/h, which translates into a travelled distance from 5.3 to 9.7 meters per one second.

During the movement of the vehicle the IoT agent tries to connect to predefined access points or Hot Spots. Shared by smartphone and other WiFi connection can also be used. It agent succeeds in connecting to Internet, it tries to send to server stored data. The flowchart of data sending is shown in Fig. 7. Agent during sending data is working according to FIFO algorithm. The structure of sending to the server data frames is as follow:

Frame := MAC, Number of measurements, {GPS position, DataTime, Type, Measurement;}

. **Fig. 6.** Dust level measurement flowchart

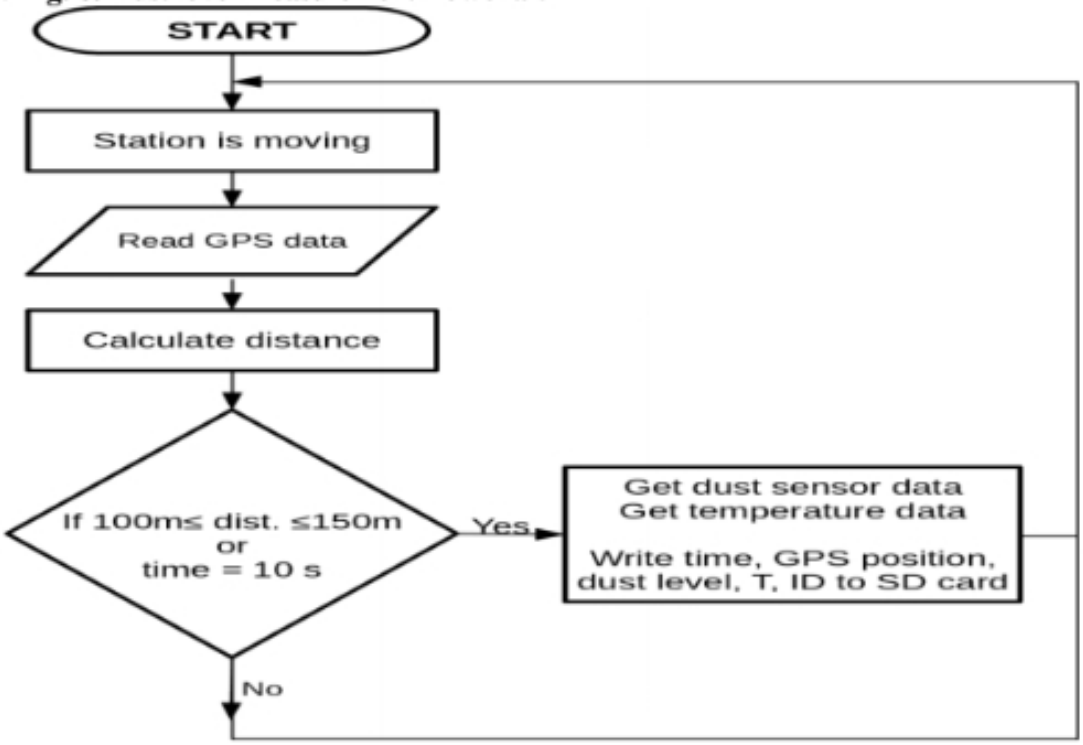

Fig . 7. Flowchart of the sending the measurement data to server protocol.

Advantages

- Data. Enhanced data collection. Instant data access. Improved data-based decision making. Time & Money. Better time management. Lower operating costs.

- The main objective of environmental monitoring is to manage and minimize the impact an organization's activities have on an environment, either to ensure compliance with laws and regulations or to mitigate risks of harmful effects on the natural environment and protect the health of human beings.

- Implementing IoT-based environmental monitoring allows for continuous detection and measurement of VOC levels in the environment. By detecting increased VOC levels at an early stage, immediate action is taken to mitigate potential health risks and ensure the safety of individuals

- Environmental monitoring or management is the process of measuring and assessing workplace conditions to evaluate health risks to workers. This practice is especially important in businesses that use hazardous substances, such as heavy metals. It includes periodic health examinations of workers and environmental impact tests.

- The advantages of environmental monitoring include preventing occupational diseases, improving the company's public image and reducing environmental pollution.

Disadvantages

- Expensive.
- Requires regular calibration.
- Difficult to analyze statistics and examine long-term trends.
- Precludes use of data in computational tools.
- The stigma around employee monitoring.
- The stigma with employee monitoring is that it negatively impacts employee morale.
- Feelings of distrust. Some employees may feel like their employers don't trust them.
- Employee privacy concerns.
- Legal issues in monitoring.