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An IoT-based Scheme for Real Time Indoor Personal Exposure Assessment

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Abstract—Air pollution is an important environmental issue that has a direct effect on human health. In this paper the development of an Internet of Things-based system for real time indoor personal exposure monitoring is described. The system was tested for real time personal exposure assessment to formaldehyde and CO₂ air pollutants. It provides accurate and real time personal exposure assessment. The real time and continuous monitoring capability makes it possible to better predict worker health risks and protect them from occupational overexposure to air pollution.

Keywords—component; Air quality; sensor networks; Internet of Things; personal exposure; real time monitoring.

I. INTRODUCTION

The human health consequences of air pollution are considerable. The world health organization (WHO) estimates that 800 000 people per year die from the effects of air pollution [1]. In addition to posing a serious public health problem, poor indoor air quality impacts worker productivity. Two fundamental information are necessary to estimate personal exposure; the concentration of pollutant in different environments and individual time activity.

Last, recent development in communication and information technology allows personal exposure monitors to be ubiquitous and part of everyday activities without significantly impact personal daily function [2,3]. The Internet of Things (IoT) can be represented as a main enabling factor of promising paradigm for integration of several technologies for communication solution. IoT have emerged to be attractive in many applications such as, health care, target tracking and surveillance. This paper proposes the implementation of an IoT-based system for real time indoor personal exposure monitoring using multi-pollutant sensors nodes to measure air pollutants concentrations in different indoor microenvironments and wearable tags for real time indoor personal tracking.

II. REAL TIME PERSONAL EXPOSURE MONITORING MODEL

The proposed model estimates personal exposures by combining the information on the measured concentration of pollutants, the movements of a worker in various

microenvironments and the time duration a worker spent in each microenvironment. In order to protect the occupational safety and health, Time-Weighted Average Individual Exposure E_{TWAi} (Represents the allowable average individual air pollution exposure for a given period of time in relation to guidelines values duration) is updated periodically and compared with the $E_{TWAi \text{ Limit}}$ based on guidelines values and country regulations. In case of exceeding individual exposure limits alert management unit triggers the appropriate action (warning, ventilation, ask worker to take a break time etc...) to ensure personal health and risk prevention. An overview of real time personal exposure monitoring model is shown in Figure 1 where C_{MEj} is air pollutant concentration in microenvironment j and E_j is individual exposure to air pollutant in microenvironment j .

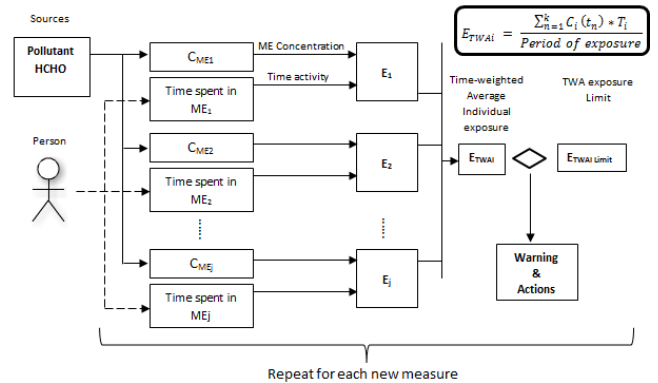


Fig. 1 Conceptual model for real time personal exposure monitoring

III. SYSTEM DESIGN AND EVALUATION

A. System architecture

The architecture of an IoT-based system for real time indoor personal exposure monitoring is shown in Figure 2. Pollutants concentrations and real time personal coordinates data are remotely collected in a data center in which data are processed and made available to users. IoT is implemented as a network of interconnected “things” (Tags and multi-pollutant sensors nodes), each of which can be addressed using unique id and communicates based on standard communication protocols.

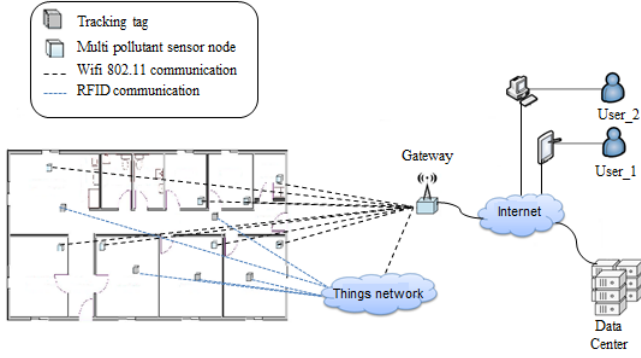


Fig. 2: System architecture

1) *Multi-pollutant sensor node*: sends periodically and wirelessly a message $\langle Node_Id, T, H, C_{CO_2}, C_{HCHO}, Date, Time \rangle$ which contains the node identifier, pollutants concentrations and the measured date and time through the gateway to a central storage system in which data are processed.

2) *Indoor positioning system*: Each employee wears a tag with a unique Id. The tag sends periodically a message contains its Id and the location_Id provides by the zone locator $\langle Tag_Id, Location_Id \rangle$ through the gateway to a central system.

3) *Data Center: central system*: The central system is a back-end server that stores gathered data and provides those data for several services. Figure 3 shows the flowchart of the algorithm. In the first case, the process detects all workers locations $\langle Tag_Id, Location_Id \rangle$ and combines location data with the newest air pollutants concentrations. Then, the process updates each individual air pollutant concentration $C_i(t_n)$ with the new received air pollutant concentration $C_j(t_n)$ where j is the microenvironment j where participant is located. In this case the time spent in the microenvironment is $T_i = t_m - t_{last}$ where t_m is the new air quality measurement time and t_{last} is the last event trigger time.

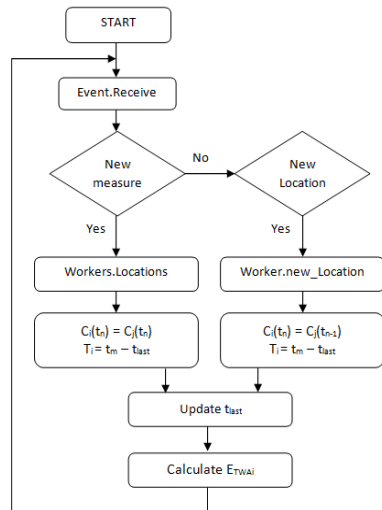


Fig. 3: flowchart of real time individual exposure assesment process

When a new worker location is received, the process updates the individual air pollutants concentrations $C_i(t_n)$ with the last received air pollutants concentrations $C_j(t_{n-1})$. In this case, the time spent in the microenvironment is $T_i = t_{mo} - t_{last}$. Finally the process updates t_{last} and calculates the time-weighted average individual exposure E_{TWAi} for each worker.

B. Results and discussion

We demonstrated that the IoT-based real time indoor personal exposure monitoring could provide effective monitoring of personal air pollution exposure at these sites. As an example, Figure 4 shows the real time personal exposure levels and E_{TWAi} (with 30 min averaging time) to formaldehyde and CO_2 . The levels of personal formaldehyde and CO_2 exposure increase sharply every time when the worker entered the copy room. The real-time monitoring capability of the IoT-based personal exposure monitor also revealed interesting details of air pollutant exposure.

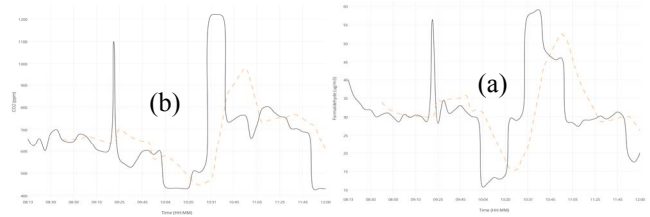


Fig. 4 : Personal exposure levels and E_{TWAi} to (a) formaldehyde and (b) CO_2

IV. CONCLUSION

The development of an IoT-based real time indoor personal exposure monitoring for real time occupational health and safety monitoring will help to be able to see high level worker exposure and their relation to specific microenvironments, sources and work tasks. This novel indoor monitoring scheme allows real time analysis of occupational air quality problems and making decision and action with regard to pollutants concentrations control policies and worker health protection. This approach can be extended to other type of pollution monitoring such as noise pollution.

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