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***Abstract*—The abstract goes here.**

***Index Terms*—IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

THE present paper presents the ongoing research under cooperation project of Riga Technical University and company Accenture. Project is motivated by two problems: a) decreased productivity while staying in crowded room; b) errors in using room-scheduling service. Both problems lead to inefficient rooms usage. Specifically paper and project are focused on meeting rooms and classrooms. Project aim is to create solution that will allow to increase rooms usage. The present paper is focused on first stage of the project task specification, problem analysis and survey of current situation.

Lets start with the description and analysis of the first problem bad health and mental productivity decrease in crowded unventilated rooms. Who might be affected by the described problem? Survey shows that almost 90% of office workers occasionally have the following problems: headache, noticeable decrease in mental abilities, fatigue, yawning. It may seem that these problems are typical and normal for hard working in office. However, medical research [4] show that the cause of these problems is insufficient room ventilation that leads to high CO_2 concentration in the air. That problem is especially noticeable for average size rooms with more than three people. Moreover, it arises more often during winter, when windows are closed most of the time. And such situations are typical for institute lectures and companies meeting rooms.

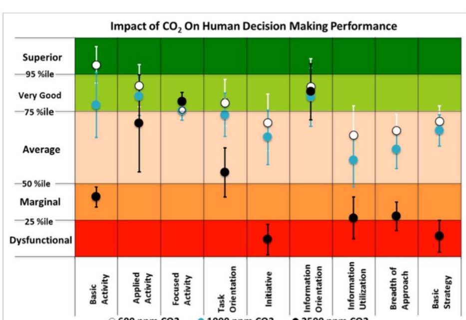

Fig. 1. Impact of CO_2 on Human Decision Making Performance

As could be seen from medical research results (see figure 1) high CO_2 concentration has biggest impact on basic mental activities, initiative actions and strategic thinking.

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All of the above mentioned applies to the situations when room ventilations is not sufficient. Therefore, arises question How much ventilation is needed? There could not be universal solution, since each room has its own parameters. CO_2 concentration depends mainly on room volume, ventilation and amount of people. Therefore there is a need in real time monitoring solution that would raise an alarm if CO_2 concentration reaches critical level. As it will be shown in further chapters, existing solutions are able to measureCO_2 level and raise an alarm, but its not possible to embed them into any other platform. Therefore we are proposing wireless sensor network capable of measuring different kind of parameters, including CO_2 concentration.

By using wireless sensor network it would be possible to create open type scalable platform. As well, proposed solution will not be limited to air quality and room occupancy detection. By integrating sensor network with cloud based services, it will allow creating decentralized system that could deliver data for different kind of user end devices.

To create proposed solution, following tasks will be solved:

- Creating wireless access protocol;
- Sensor network integrating into existing cloud service Windows Azure;
- Enhancing sensor nodes energy efficiency;
- Encrypted data transmission protocol realization.

II. Related Work

There exist variety of systems that have been proposed or developed in recent years for indoor environment monitoring. In this chapter we introduce readers to some of them.

[2] is a theoretical research on environment monitoring. They provide necessary constraints and measured phenomena to implement any of structural, indoor and extreme event monitoring. For indoor environment monitoring temperature, humidity, true-light sensors, infrared-based presence sensors, and chemical sensors are useful and every environment monitoring application should consist of at least of these sensors. They as well point out that "interdisciplinary collaboration between researchers from computer science and structural engineering" is a key requirement for the monitoring of large public buildings.

In [3] is a research that by surveying more than 150 persons in Europe and Asia provide information of what environmental factors are important and how to present them to users, to build indoor environment monitoring system. The emphasis is put on designing easy to use and easy to understand user interface of such systems.

One example of environmental monitoring is buildings power consumption monitoring. [4] is such an example. This paper provide a description of the power monitoring system in terms of implementation and use, as well provide some examples of the benefits and savings that have been achieved through its use. By monitored values they calculate: (1) percent power use is calculated for each distribution panel and for each tenant, (2) tenant estimated energy cost month to date, (3) estimated CO_2 emissions month to date and (4) power use per unit area (watts per square foot). Which then is used to identify and prioritize HVAC optimization programs as well as to assess and quantify the effects of changes on energy consumption.

[4] presents a Building Monitoring system based on Wireless Sensor Networks - BMWSN. Which is a clustering-based network specified for building environment monitoring. In this system temperature/ humidity sensors (SHT11), light sensors (STL2550), and human detection sensors (BISS0001) are used. The cluster-heads perform data aggregation and form a tree hierarchy to forward data to server. System implements simple alarm messaging to inform user of exceeded environmental variables, but no active environment control is implemented.

[6] presents development of a smart sensor network which allows the monitoring of the parameters in the workplace required for ergonomic assessment of working conditions. Phenomena measured are temperature (TC1047A), humidity (HCH-1000), intensity of light (OPT101) and ambient noise (SPM0404LE5H-QB-38342). Proposed system is tested in very small scale compared to the previous systems, but provides insight of how environmental parameters can be measured in workplace.

Besides distributed indoor environment monitoring systems there are other methods used for the same purpose. One such method is by using handheld devices. They are frequently referred to as "Indoor Environmental Quality" instruments. Price for such devices is usually very large drawback, because one such device can cost even several thousand US dollars, furthermore data often can be used only locally or best case scenario saved on SD card. But on high side of such devices is accuracy and variety of sensors in such device. For example IEQ Check^{TM} produced by Bacharach can use up to 7 differnet sensors - temperature, relative humidity and variation of Carbon Dioxide (CO_2), Carbon Monoxide (CO), Oxygen (O_2), Formaldehyde (HCHO), Total Volatile Organic Compounds (TVOCs), Nitrogen Dioxide (NO_2), Nitric Oxide (NO), Sulfur Dioxide (SO_2), Ammonia (NH_3), Hydrogen Sulfide (H_2S) and Combustible Gases [7]. Other devices can even detect dust (even nano-scale), measure airflow [8]

III. Proposed System Architecture

As previouse research shows none of existing solutions can be reused entirely being a solution for our reasearch problem. Thus we have worked on a proposal and netwroks architecture that might solve both problems: meeting room reservation vs. actual utilization monitoring and scalable solution for monitoring and analysis of office environment.

Referring to figure 2 where a scheme for the proposed Internet of Things office environment monitoring solution is depicted the main parts of the system can be discussed. The system consists of two main parts: on-site destributed heterodenouse wireless sensor network and sensorial data storage and processing warehouse formed using cloud computing technology, here Azure provided cloud platform has been selected.

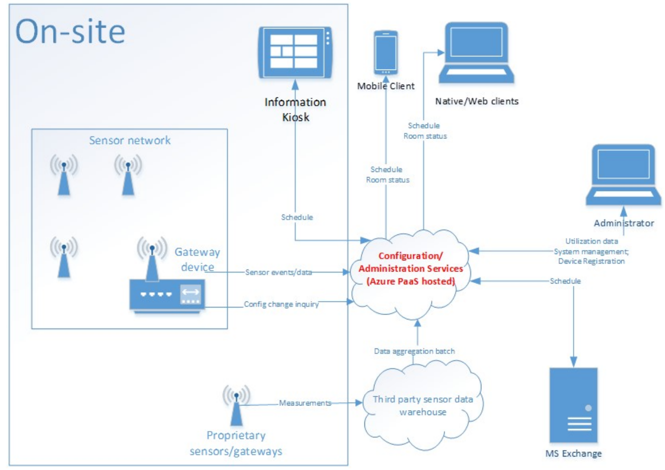

Fig. 2. Scheme for the proposed Internet of Things office environment monitoring solution.

On-site sensor network is heterogenouse because of three different types of heterogenousity:

- Communication protocols - In the current work we are combining different communication protocols. Sensorial data may be trasfered via proprietary protocol stack and/or standard-based protocol stacks. Here we are testing our designed highly-scalable WSN protocol stack's interconnection with different standartized solutions, like ZigBee and Wi-Fi enabled nodes.
- Sensor nodes' hardware - since there are presented two ZigBee and Wi-Fi communication protocols based on standards it is obviouse that corresponding sensor nodes should have thase standards enablement hardware. For instance to implements ZigBee communication sensor node should be equiped with IEEE 802.15.4 fully compatible radio chip. As well to enable platform readiness for Wi-Fi protocol stack corresponding devices should enable 802.11b/g/n support in the hardware layer, too. Apart from these two examples third one the proprietary protocol stack can not be so demanding on particular hardware since it should only satisfy the very basic software needs.
- Powering mode - mostly wireless sensor nodes are battery-powered devices. But in the current solution we have NetAtmo Wi-Fi-enabled sensor nodes powered as trough battary as well via power line. Such combination is provided because of architectural limitations of that solution: there is a GW and only some sensor nodes, normally only one per GW. ZigBee solution needs different type of nodes, too. Tey are: coordinator, router and end device, where coordinator and router nodes with greate probability may be asked to be constantly powered because of the scenario they are fulfilling. Talking about proprietary WSN there might be both powering modes

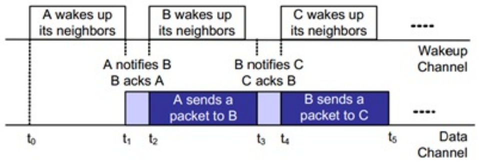

Fig. 3. Pipelined wakeup procedure in PTW

with different sensor nodes.

It is clear that sensorial data should be collected on wireless sensor layer and trasmitted to the cloud platform. Since we have three different technologies selected as parts of WSN, the trasnformation component(-s) should be provided. That component, here it is a Gateway will gather data from one protocol stack and transfers it to another one, here via TCP/IP protocol stack

IV. WSN Layer Implementation

A. Energy Saving Operation

The energy cost of transmitting a single bit of information is approximately the same as that needed for processing a thousand operations in a typical WSN [1]. The lifetime of a sensor network can be extended by jointly applying different techniques. For example, energy efficient protocols are aimed at minimizing the energy consumption during network activities. However, a large amount of energy is consumed by node components, CPU, radio, sensors, etc., even if they are idle. Power management schemes are thus used for switching off node components that are not temporarily needed [2]. NRF24L01 radio chips were used in this project. It consumes 12.3mA receiving data at full speed (2Mbps on-air data-rate) and 11.3mA sending data at 0dBm. Using simple batteries with this transceiver, WSN will operate approximately for 35 hours if only communicating. WSN also consists of several sensors that also will consume battery energy, so it reduces lifetime to approximately 24 hours. Energy saving methods can extend WSN lifetime for more times. Using SLEEP/WAKEUP protocol proposed in [2] is possible that WSN will work for months without batteries change. WSN can use a Pipelined Tone Wakeup (PTW) scheme proposed in [3]. There are two different channels for wakeup signals and data. In wakeup channel transmits only wakeup tone to awake neighboring nodes.

Lets suppose that node A has to transmit a data message to node C through node B. At time t_0, A starts sending a wakeup tone over wakeup channel. This tone awakes all As neighbors. At time t_1 A sends a notification packet to node B on the data channel to inform that the next data packet will be destined to B. All As neighbors, instead node B, learn that the following message is not intended for them and they turn off their data radio. Instead, B realizes to be the destination of next data message, and replies with a wakeup acknowledgment on the data channel. After acknowledgement, A starts transmitting the data packet on the data channel. At the same time, B starts sending a tone on the wakeup channel to awake all its neighbors. As shown in fiure 3, the packet transmission from A to B on the data channel, and the Bs tone transmission on the wakeup channel are done in parallel. As the WSN will be used in offices with known work-time, then all nodes will work at this time. After work-time all nodes power off all sensors, radio and then go to deep SLEEP mode. According to office, nodes will WAKEUP several minutes before work-time starts. CO_2 sensor can be disconnected from power or be connected only to make a few measurements of the air, and then again disconnected. This will give significant energy economy, because there is known that the air quality is best before work-time.

B. Secure Communication

To create the reliable system it is needed to ensure data protection at all layers. Since wireless sensor nodes are limited in computational resources, it is not possible to use typical encryption. As a solution to existing problem it is possible to use Elliptic curve cryptography. It would allow establishing data protection comparable with typical encryption protocols like TLS, but using less computational resoursec. ECC - cryptographic schemes based relying on scalar multiplication of elliptic curve points. For elliptic curves, the problem assumed to be intractable is finding the discrete logarithm of an element. [5] Key in elliptic curve cryptography can be shorter, but still offering same security as RSA. For example, a 160-bit ECC key provides the same level of security as a 1024-bit RSA key, and a 224-bit ECC key provides the same security as a 2048-bit RSA key. Smaller keys mean faster computation, lower power consumption, and memory and bandwidth savings [6].

V. Conclusion

The conclusion goes here.

References

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