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Introduction of flexible monitoring equipment into the Greenlandic building sector

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Abstract

Greenlandic winters are long and cold so living inside the heated and properly ventilated space requires quite some energy. It is assumed that in mechanically ventilated buildings, significant amounts of energy for heating can be conserved by adjusting the ventilation flow rates according to actual demand of the occupants. Traditional solutions available on market consist of controller and sensors in the living space detecting the occupancy and activity (movement sensors, CO_2 sensors, Humidity sensors, etc.). The controller needs to be programmed and maintained by an expert and sensors need to be hardwired to the controller. In Greenland where price of the labor is very high and availability of experts limited the installation of such control system becomes unacceptably expensive, particularly in case of renovation of existing buildings. One possible solution to the above is to introduce wireless sensor network (WSN) technologies. The design of a prototype wireless monitoring and control system is demonstrated in the new dormitory Apisseq in Sisimiut, Greenland. The existing mechanical ventilation was running at a constant air volume even during unoccupied hours which resulted in a very high heat demand. It was estimated that installing the WSN system will bring annual savings of 1,600 € at the investment of 8,000 €. This paper describes the initial setup of the system and discusses its advantages and drawbacks.

1. Introduction

The Arctic climate is cold, so living inside heated buildings requires great amounts of energy. In Greenland households account for 25 % (85 % is heat and 15 % is electricity) of the total energy consumption (Statistics Greenland 2011). The average heat consumption of households in Greenland was 387 kWh/m^2 in 2009 (Statistics Greenland 2011). Additionally, another 25 % of the Greenlandic energy is used to deliver energy and water to the consumer (including households) hence the real contribution of households to the overall energy use is higher than 25 %. With the intention to reduce the CO_2 emissions, the overall energy use needs to be reduced accordingly. Given the amount of energy used in buildings, these cannot be excluded from the process of energy conservation. To reduce the energy use, buildings will become more insulated and air tight to minimize heat losses. Furthermore, the buildings need to be equipped with advanced heating, ventilation and air conditioning (HVAC) systems to ensure healthy and comfortable indoor environment. It has been shown that by optimizing the operation HVAC systems according to occupants' actual demands can bring further substantial energy savings (Nielsen and Drivsholm 2010; Laverge et al. 2011). However installing conventional wired control systems may become costly particularly in case of retrofits as the expenses related to installation of the systems are high. A special case is buildings in remote regions like Greenland where availability of professional labor is limited and expensive.

A possible way to reduce the installation costs is the use of Wireless Sensor Networks (WSN) to monitor and control buildings. The purpose of this study is to develop WSN based monitoring and control system and implement it into an existing building with HVAC system. This should bring energy savings without negative effects on indoor air quality (IAQ). Furthermore it should be demonstrated that the investment is lower than the conventional wired solution and the return on investment is reasonable.

2. The building description

The studied building is a dormitory for engineering students Apisseq in the town of Sisimiut, Greenland. It was built in 2010 with the intention to demonstrate energy efficient building in which the modern technologies, not yet commonly used in the Arctic, could be installed and tested. Previous studies undertaken in this building have shown, that the poor design of the ventilation system causes that the building is constantly over-ventilated (Kotol and Rode 2012) which in such cold climate means significant increase of the energy use.

2.1 Layout

The building has a circular shape and consists of three floors: a ground floor with technical rooms and two upper floors with flats, laundry and common room. There are 33 single room flats for one student and 4 double room flats at the gables of the building (see Figure 1).

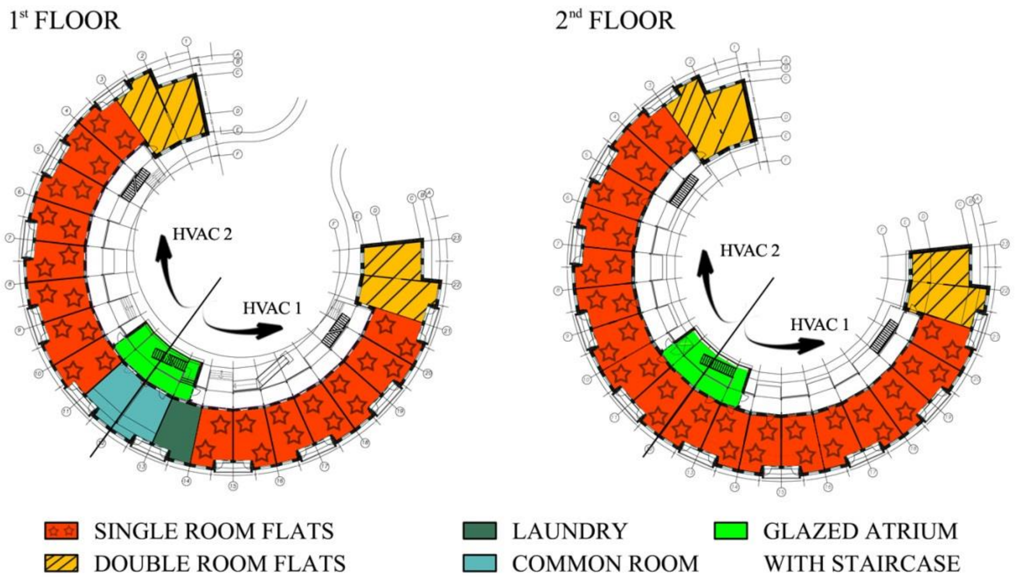

Figure 1. Floor plans of the engineering dormitory Apisseq

More detailed description of the building can be found in (Kotol and Rode 2012; Vladyková et al. 2010). The annual heat demand was estimated to 160 MWh/yr for space heating and 80 MWh/yr for domestic hot water (DHW). In total the predicted annual heat demand was 240 MWh/yr or 169.7 kWh/(m^2·yr). However, the real annual heat demand in 2012 was 310 MWh/yr or 219.7 kWh/(m^2·yr). Out of which, 18 % was dedicated to heating of the ventilation air. This in terms of running costs resulted in total annual energy bill of 30,000

€ in 2012 (of which 5,400 € was related to ventilation air heating).

2.2 Ventilation system

The ventilation system consists of two identical HVAC units. Each of them is venting half of the building as shown in Figure 1. The units deliver fresh air to the living space of each flat and extract the polluted air through range hoods and bath rooms of each flat. The supply air is delivered at a constant rate whereas the exhaust air flow can be increased in case of increased humidity in bathrooms or cooking activities but at the normal operation the ventilation is balanced and provides the air change of 1.1 h^{-1}. Nevertheless, the current Greenlandic building regulation (GBR) (Direktoratet for Boliger og Infrastruktur 2006) requires the minimal air change of 0.5 h^{-1}. The GBR also requires that the following rooms should be equipped with air extraction: Kitchens (20 l/s) and bathrooms (15 l/s). This additional requirement was likely the reason for designing the constant ventilation rate of 20 l/s (air change of 1.1 h^{-1}). However, the required extraction from kitchens and bathrooms is meant to be available when needed and does not have to be on at all times. It is expected that substantial energy savings can be achieved by reducing the ventilation air change according to the actual demands (occupancy) without negatively affecting the indoor air quality.

3. Methodology

To detect the actual occupancy and estimate the right amount of ventilation air needed for the space, CO_2 concentration is often used. Some European standards suggest that in case of demand controlled ventilation where indoor CO_2 concentration is used as an IAQ indicator the ventilation rate can be adjusted in order to maintain the indoor CO_2 concentration below certain level [1000 ppm (Danmark. Erhvervs- og Byggestyrelsen 2010) or 500 ppm above outdoors (Dansk Standard 2007)]. The minimal air change of 0.05 $l/s{\cdot}m^{-2}$ to 0.1 $l/s{\cdot}m^{-2}$ (Dansk Standard 2007) should however always be maintained.

3.1 Experimental setup

In this experiment the ventilation system in one half of the building will be adjusted to reduce ventilation rates according to actual demands of the occupants. The other half of the building will remain unchanged to provide a reference case for evaluation of the improvements.

Due to the design of the ventilation system and the fact that the building is already finished and in use, the space for improvement is rather limited. For that and for economic reasons it would not be economically feasible to control the air flow on a room level. Nevertheless, as the building is a dormitory for students with similar schedule, it can be expected that their daily routines will have a similar pattern for majority of the time. Therefore the air flow will be regulated centrally on the ventilation unit level.

Although the air flow will be adjusted centrally for the entire half of the building, it is still important to make sure that none of the flats will be insufficiently ventilated. Therefore a CO_2 sensor will be placed in each flat. To avoid excessive installation costs related to hard wiring each sensor, the sensors will communicate wirelessly with the central node. The central node will evaluate levels of CO_2 in the rooms and send a control signal to the actuators which will adjust the air flows. The actual air change will be controlled in the range between 0.02 h^{-1} and 1.1 h^{-1} in order to maintain the CO_2 concentration in each room below 1000 ppm.

Furthermore the central node will be accessible on-line which will further reduce the costs as all the programming, calibration, software maintenance, troubleshooting and data collection and evaluation can be done remotely from anywhere in the world.

4. Hardware

The Libelium Waspmote platform creates the foundation of the setup and was preferred because of its modularity, which made it

possible to build custom nodes for specific purposes.
The experimental setup consists of three different node types (each designed for a specific purpose), a signal amplifier and damper actuators which control the airflow.

4.1 Central Node

The central node creates the wireless network, it can be used as a router for message passing and it saves data from the network in persistent storage. Additionally, the node enables the online access and remote control. The coordinator node selected for this experimental setup is the Meshlium ZigBee-PRO-AP.

4.2 Sensor Nodes

The sensor nodes monitor CO_2 concentration in each flat and send the data to coordinator node. The proposed system contains 18 sensor nodes (one in each flat). The main components of the nodes are Waspmote ZigBee PRO, Gases Sensor Board v2.0 and solid electrolyte CO_2 Sensor TGS 4161. Each node has a 6.6 Ah battery which will be able to power the node for a year. However, for the experimental purposes each node will be powered from the electrical grid as a backup.

4.3 Control Node

The control node (Waspmote ZigBee PRO) receives the commands from central node and by means of two actuators (Belimo TF24-SR) adjusts the supply and exhaust damper positions (and thus air flows). Because the voltage range given by control node is 0 V to 3 V and the actuators require a signal from 0 V to 10 V an amplifier was needed. For this purpose a programmable relay Siemens LOGO which is already a part of the building's inventory was used.

5. Economy

Excluding the Belimo actuators and Siemens LOGO relay (which are already installed in the building), the retail price of the wireless solution was 8,000 €. For comparison the price of the wired solution would be 16,000 € (according to Table 1).

Table 1. Price estimation for the wired solution

Item	Price (incl.VAT)
CO_2 sensors (Vaisala CARBOCAP® GMW 22)	6,000 €,
Programmable logic controller with web server (Prolon PID 4000) including installation	4,000 €
Installation of the sensors	6,000 €
Total	**16,000 €**

Expected annual energy savings brought by this solution are 15 MWh/yr or 1600 €/yr at current price of the heat. This yields simple payback time of 5 years compare to 10 years with standard wired solution.

6. Discussion

The price of the wired solution is higher partially due to use of different CO_2 sensors. The Vaisala sensors use more accurate technology and do not require such frequent calibration (the manufacturer guaranties 5 % accuracy over the course of five years). On the other hand the wireless solution allows remote calibration on as frequent basis as required by the sensor manufacturer, therefore more accurate sensors are not needed.

The price for installation of the wireless sensors has not been included in the calculation as that will be performed by the researchers. However, installing the wireless solution only requires attaching the sensor nodes to a wall in each flat and connecting the central node to the internet (the rest is done remotely). This is apparently less labor intensive than wiring each sensor through the finished building in use. Moreover it does not require highly skilled professionals to perform this work.

The actual payback period will strongly depend on the real energy savings and will also be affected by the energy price. The price is expected to be rising every year which will further shorten the payback period.

One of the advantages of WSN solution is its flexibility/expandability. If in the future the system needs to be expanded by large number of sensors (e.g. including the other half of the building), these can simply be added to rooms without the need for additional central node. Contrary the wired solution has a limitation in maximum number of inputs from sensors, once this number is reached, additional hardware must be installed.

A possible drawback of the WSN solution can be its robustness and long term reliability. These will be tested during the experiment.

7. Conclusions

It was found that it is economically beneficial to use WSN instead of traditional wired solutions in remote areas with expensive labor and limited availability of highly skilled workers.

The simple payback period is 5 years which will probably be even shorter due to increasing price of energy.

The real energy savings and actual payback period along with the reliability of the solution will be confirmed by the experiment.

Acknowledgements

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References

Danmark. Erhvervs- og Byggestyrelsen. 2010. *Bygningsreglement 2010 (BR10)*. Kbh.: Erhvervs- og Byggestyrelsen.

Dansk Standard. 2007. *DS/EN 15251 - Indoor Environmental Input Parameters for Design and Assessment of Energy Performance of Buildings Addressing Indoor Air Quality, Thermal Environment, Lighting and Accoustics*. Charlottenlund: Dansk Standard.

Direktoratet for Boliger og Infrastruktur. 2006. *Grønlands Bygningsreglement 2006* Direktoratet for Boliger og Infrastruktur.

Kotol, Martin and Carsten Rode. 2012. *Energy Performance and Indoor Air Quality in Modern Buildings in Greenland*. Proceedings of the 7th International HVAC Cold Climate Conference.

Laverge, J., N. Van den Bossche, N. Heijmans, and A. Janssens. 2011. "Energy Saving Potential and Repercussions on Indoor Air Quality of Demand Controlled Residential Ventilation Strategies." *Building and Environment* 46 (7).

Nielsen, Toke Rammer and Christian Drivsholm. 2010. "Energy Efficient Demand Controlled Ventilation in Single Family Houses." *Energy and Buildings* 42 (11).

Statistics Greenland. "Http://Www.Stat.Gl.", last modified 14.11.2011, accessed 10.6.2011, 2011, http://www.stat.gl.

Petra Vladyková, and Martin Kotol. 2010. *Monitoring System in New Dormitory APISSEQ, Sisimiut, Greenland*: DTU Byg.