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Article

REVIEW OF WIRELESS SENSOR NETWORKS IN BUILDING AUTOMATION SYSTEMS

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ABSTRACT

Wireless Sensor Networks (WSN), which is being employed in Building Automation Systems (BAS), are an effective tool to monitor various parameters and help automate these systems. WSN prove to be more reliable and efficient than traditional systems which employ cabled networks, and are used in various applications like security, appliances control, Home automation etc. But, use of WSN in automating Plumbing systems has not attracted much attention. Implementing WSN to detect pipe failures and ensure a good health of Water and Drainage system is necessary to improve the lifetime of these systems. This paper reviews the work that has been done in implementing WSN in BAS and detection of Pipe failures.

Keywords- Wireless Sensor Networks, Building Automation Systems, Pipe failures

INTRODUCTION

WSN's are one of the most promising technologies which is attracting a lot of attention in recent times. Because of high costs, more energy consumption and complexity in working with wired networks, WSN proves to be a good alternative. It acts as a gateway between the wired world and the distributed sensor nodes, hence allowing us to merge both the systems. It employs a clustering based network structure wherein small sensor nodes send data to a central server by using various techniques. WSN has extensively been used in a variety of applications like military purposes, automation in residential and official buildings. WSN is gaining attention in Building Automation because of its ability to monitor different parameters, perform analysis and evaluation on the data collected and take necessary actions.

BAS employs WSN to monitor and automate various tasks like controlling electric appliances [1], heating, ventilation and air conditioning (HVAC) control [2], security [3] etc. Different parameters like temperature and airflow, and position of intruder are monitored by the sensor nodes and sent to central server using WSN techniques. Use of WSN in BAS allows more flexibility, less energy consumption and removes the need for wires. Sensor nodes can be designed to save energy by going in sleep mode when not sensing the data [4]. Data aggregation techniques have also been used in WSN to eliminate information redundancy and data transfer in compact way [5].

Implementing plumbing monitoring in BAS is yet unexplored. Not much work has been done to integrate Water Supply and Drainage Management with WSN. Plumbing Monitoring is essential to ensure the good health of Pipeline system [6]. Various leakages and pipe failures can affect the lifetime of Plumbing System. There is a need to detect these failures and leakages with the use of WSN in order to make the detection efficient, convenient and reliable. By understanding the factors which lead to pipe failure and leakages, an effective system to monitor these faults can be developed.

In this paper, we present the study of the work done in implementing PMS with WSN. The rest of the paper is organized as follows. In section 2, we explain the necessity for implementing Plumbing Management using WSN. Section 3 presents the study and survey of the work done in implementing WSN in BAS. Section 4 explains various techniques that have been implemented for monitoring and detecting the failures in pipes and water distribution networks. Finally in section 5 we conclude and comment on the scope of future work in this area.

NECESSITY FOR PLUMBING MONITORING SYSTEM

Concealed plumbing is a popular system implemented in today's buildings wherein all the pipes are concealed behind walls. Leakage and fault detection is one of the most important issues that need to be addressed in concealed plumbing. Due to the concealed nature of pipes it is difficult to detect the exact location of the fault. Hit and trial methods are usually the only solution to find these faults. Hence, a need for a contiguous detection system employing sensors and WSN techniques arises. Use of WSN to detect leakage and faults is yet unexplored to a great extent.

Using different sensors to sense parameters such as temperature, pressure, humidity and water flow along with a defined wireless network topology to transmit the information to a central server is the most important aspect of PMS using WSN. Research regarding the effects of temperature in cold regions [7] has shown that pipe freeze occurs when temperature falls below 20° F. It is not necessary that leakages occur at the location where ice blockage happens. Instead, continuous freezing causes water pressure to increase downstream, which leads to pipe bursts.

Plumbing Monitoring System (PMS) can use temperature sensors to facilitate the detection of failures caused by temperature irregularities. Pressure sensors can be placed at suitable distances to monitor change in pressure which can potentially cause pipe bursts. Because of blockages, pipes may experience internal pressure and it may eventually lead to leakage. By monitoring the pressure continuously and comparing it with set threshold values, it can be ensured that pipe failures don't occur because of excess pressure. Two flow sensors can be used to track blockages at pipe bends. Humidity sensors can also be employed to detect leakages effectively. If at all any leakage occurs, humidity sensor will detect the increase in moisture around the pipe, which has been caused by the dripping of water from the leakage spot.

We observe that PMS are vital to detect forthcoming faults; thereby preventing hazards like pipe bursts and hence, WSN are the best solution for handling problems related to plumbing systems.

WIRELESS SENSOR NETWORKS IN BUILDING AUTOMATION SYSTEMS

Building automation systems monitor and control HVAC and help to manage building facilities, automation of meter reading etc. WSNs comprise of battery-powered nodes which are connected with the base station for a task. One of the most important aspects of WSN is the lifetime of its nodes and its energy consumption, since sensors have to operate with limited energy [5]. Battery-powered nodes become dead after prolonged use which may lead to disruption of WSNs operation.

Using energy in a well-organized way is necessary to increase the lifetime of WSN's. Qidfen Dong et al have used a clustering-based network for building monitoring that is inspired by LEACH (Low Energy Adaptive Cluster Hierarchy) method [7]. Two main ideas are used to implement the clustering-based network.

1) The configuration module of building management software, which does not consume node energy, is used to conduct all nodes in a room forming a local cluster.

2) Cluster-heads cannot directly transmit packets to the sink node due to limited wireless communication range and are represented by a multi-hop tree rooted at the sink node.

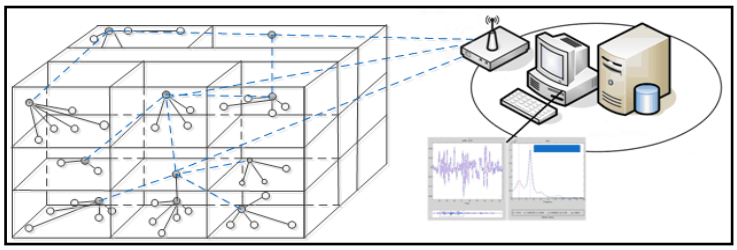

Figure 1: Wireless Sensor Network for building monitoring

In WSNs, an important method called data aggregation is used for the transmission of data. It is the process of compressing locally, the data gathered by the sensor nodes so that only compressed data travels across a number of hops to their destination. The sensor nodes keep their transceivers off most of the time in order to preserve their batteries and these are the sleep periods of the nodes. If the nodes sleep for long periods, the tree construction time is divided by the number of hops. For a fixed maximum delay, this allows us to extend the sleep periods and save energy. This comes at the price of an aggregation tree with degraded performance [8].

Thus techniques like energy consumption of nodes, clustering based network and data aggregation are further used to improve the efficiency of WSN.

PIPE FAILURES DETECTION

Implementing PMS in BAS is needed, since one of the important objectives of BAS is "To monitor and correct the system and also to alert or sound alarms when needed". Some work has been done in detecting pipe failures. Sean Morefield et al have used acoustic sensors placed at an effective distance of 1000 feet to detect the leakage's position. The method is effective in detecting leakage as small has 0.1gal/hr and applicable on wide range of pipes. The Government of India has established a Standard code for practicing plumbing multi-storied buildings in India wherein they have mentioned the estimation of water supply demand, distribution system, design of pipelining

system, pumping system, standard water pressure, flow rate and back flow, and pipe materials and specifications.

M.Bergman et al [9], in their paper have shown that their procedure proves to be an efficient and reliable method in estimating the probability of pipe break failures in nuclear pipelining. The paper suggests that larger the pipe diameter, smaller is the failure probability. Moreover leak detection is a very important factor in order to maintain a low failure probability. It also concludes from the various case studies performed that with Detection limit for leak rate, d=0.3kg/s, inspection must be done every 3 years. John Rostum [10] has used statistical models for predicting failures for each pipe in a water distribution network and determined whether or not the already existing data in Gemini VA is sufficient input for these models. The author has made 2 classes of regression models for prediction failures:- 1) Proportional Hazard Model (PHM) which is generalization of survival data analysis in which he suggests use of a parametric model like Weibull PHM instead of Cox's semi-parametric mode l. 2) A counting process (i.e. Non homogeneous Poisson process (NHPP) for which a computer program was developed to estimate the maximum likelihood for the parameters in the NHPP. The author has found that Model predictions were more reliable for groups of pipes (network level) than they were for individual pipes and minimum number of observations was required to obtain reliable model results. The author did a case study for the water network in Trondheim, Norway from which it was difficult to draw definitive conclusions yet the author suggests that the NHPP appears to be better at predicting pipe failures than the Weibull PHM approach.

M.J. Fadaee and R. Tabatabaei [11] have presented a statistical model for predicting failures for each pipe in a water distribution network. The author modeled the effects of failures modes and repairs using a modified power law. Using their model in numerical examples for urban water network, they concluded that after each repair, water network failure intensity is reduced to a great extent. Also the parameters of the model have been calculated by Maximum Likelihood Estimation (MLE). Also Instantaneous Intensity Failure (IIF) and other such cumulative failures have been estimated. Such statistical models prove to be a useful tool to detect Pipe failures.

We observe that various models have been developed to facilitate the detection of pipe failures. However further work needs to be done to implement these models in a practical way in order to detect pipe failures by using WSN.

CONCLUSION

Review of existing work in the Building Automation System domain suggests that pipe failure can be detected effectively. Different types of bends and shapes of pipes can lead to different types of pipe failures. Study of the effect of temperature, pressure and the types of pipes on the pipe failure probability is needed in order to establish a strong relationship between them. Also, implementing WSN in PMS will require a focus on parameters like battery life of the nodes, energy routing protocols, data aggregation techniques, parameters monitored by the nodes etc in order to make the system more efficient, reliable and cost effective. We further aim to work on fault detection in Water Supply and Drainage Management System in high-rise buildings using Wireless Sensor Networks.

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