Investigation of Multi Hop Sensor Node Data Aggregation in Building Management System

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Abstract
BMS or Building Management Systems is the automation of building systems and plays a vital role in the monitoring of mechanical and electrical equipments. The advent of smart sensors have led to improvement in processing power, which is more flexible in incorporating new innovations, as well as energy conservation schemes. Due to lack of automation in the conventional WSN networks, switching ON or OFF can lead to the participation or nonparticipation of the CH process. This paper aims at implementing a rule-based Intelligent Multi Hop LEACH, adapted for BMS-WSN framework consisting of heterogeneous sensor nodes with different amount of battery power / energy source. Experiments show the proposed technique outperforms multi hop LEACH in terms of energy savings and packet delivery ratio.

Keywords: Wireless Sensor Network, Building Management Systems (BMS), Data aggregation, Multi-hop routing, LEACH, Energy Savings.

Introduction

WSN is gaining importance because of their application in the fields of military, daily functions, and new inventions in the field of medical technology. WSN also play a vital role in the monitoring of changes in environment. One other important application of WSN is their capacity to function in ecosystems where monitoring by men are risky, inefficient or at times not feasible.

WSN is a non-infrastructure network which is made of numerous cost efficient sensor nodes with limited power but at the same time multi-functional capability. Sensor nodes possess 4 components, namely, sensing, processing, communication, and power unit. The main challenge in the use of sensors is that their power is restricted and the batteries are not rechargeable. So, the most important factor which should be taken into account when the sensor nodes are designed with regards to safety measures[1]. By limiting the energy consumption, battery life can be extended.

Multi-hopping helps in the communication of a sensor node which is not within the radio range of each other through intermediate nodes. There is flexibility of the addition of or removal of nodes in a network. Every network is grouped into a number of clusters which is called clustering. In every cluster, a node is chosen to be cluster head (CH) while the remainder are Cluster Members (CM). The sensor nodes are correlates with each other in communication.

In a given data, redundancy is removed and is forwarded to sink by CH, which gathers the information from its members as well as aggregates it. As energy consumption by CH is more, nodes with higher remaining energy act as Cluster Heads by rotation such that all the nodes lose their energy at an equal rate.

Clustering helps in the coordination of the sensors locally and effectively in achieving global goals including scalability and effective utilization of resources. Scalability is nothing but the flexibility of the system in performing effectively even if the size of the system increases. Depending upon the size of the area of interest, many sensors have to be deployed for any particular given task as the transmission range of the individual nodes are limited. Thus, the particular routing scheme should be capable of working with large numbers of sensor nodes[2].

Adaptability or scalability is one important requisite of WSN. All techniques involved in WSN must be in a position to adapt to a large range of network sizes. Many unclustered node metrics are used to measure the efficiency of the proposed protocols with reference to scalability. It is to be noted that a large number of unclustered nodes indicate a lower performance with effect to protocol's adaptability.

The next important requisite is data aggregation that is the procedure of gathering and consolidating information which is helpful. This is very vital in energy conservation. In WSNs, data aggregation is the best method in saving resources which are available. The prime aim of data aggregation in WSN is gathering as well as consolidating information in a power conserving fashion, so the life of a network could be improved.

Generally, data come from various sources, and en route redundancy needs to be eliminated, and at the same time, the number of transmissions should be minimized thus saving energy. This pattern proves that the conventional address oriented approaches are outdated which runs between a pair of addressable end-nodes, whereas, the present protocol is a more data-centric approach that finds multiple routes to a single destination and permits in-network merger of redundant data.

Mostly sensor nodes are used in remote environments, while multi-up WSN is used if the area is large; rarely though sensor distribution is used globally. So, when users request

the state-based sensor metrics of parameters such as temperature, humidity of a random area, it might result in heavy unpredictable traffic. Such problems can be solved using data aggregation that can satisfy the users' needs and at the same time manage overlapped aggregation tree of numerous users effectively. In light of the effectiveness of WSN, numerous factual functions such as observation of the ecosystem, applications in armed forces and investigations in the field of science and analyzing their use.

Data aggregation is nothing but the selection and storage of accumulated format for evaluation and usage where the criteria of the node joining the cluster are used. Aggregation is the methods which models data as well as info in a spatial setup so that their storage and recovery is easy. The information is stored and collected in a data base server and a particular data collection technique is followed. The data items stored are related and are stored in accessible data form.

The challenges faced until recently are of the energy consumed by the battery, highly effective consolidation of the information, and apt methods used in the with proper decision making abilities. Hence this work aims at effective management of the above-mentioned issues using basic principles such as collection of data for cluster head, techniques for aggregation of data using data cube aggregation and calculation of global weight of nodes.

Due to the growth of science and technology, the consumers are aware of their needs and they are very sure of them being provided with facilities of their money's worth. Moreover, the inhabitants of the building should be aware of the structural strength of their building, the need for automation to increase their comfort level, with the usage of automation in power conservation approach. This can be done only with the aid of sensor as well as actuator inside the building structure.

WSN may be used to monitor and control equipments such as the electrical equipments in the building, heating and cooling mechanisms, ventilation, the installation of which can done with less effort in a building. This would help in effectively monitoring the building space and energy used such as in electricity, gas, and water and facilitating the intelligent actuation of devices in the buildings.

BMS refers to a software high-technology, computerized system that is set up in a building to monitor as well as control equipments as well as facilities. The following are the equipments which can be added under BMS: air handling, as well as cooling plant system, lightings, power system, fire system as well as security features.

BMS is defined as a combination of hardware and software and is complex, at multiple levels, with many objectives, and also integrated inter-related, as well as is an entire intelligent design management information system[3]. When there is restriction in the installed plant, the BMS is capable of automating as well as taking control of facilities' operations as well as actuators in an effective manner suitable for business.

Intelligent Building Management Systems is a component of the bigger information systems within the area of future 'Internet of Things.' Through this system, the manager in the building can perform management of power usage as well as obtain energy as well as in the maintenance of the building systems. Thus, the reliability of WSN in building automation is making the maintenance of the work spaces in the building which are energy efficient and healthy and also very efficient with respect to costs.

Wireless sensing in commercial spaces or offices have created increasing awareness in the condition of buildings and their systems. The major advantages of this are:

- The lifespan of the equipment and electrical appliances is increased.
- The building environment of the occupants is improved.
- As the monitoring and tracking of the status of the building structures is centralized the process is more economical and cost effective.
- Fault detection is effective and thus the energy usage is minimized with increasing reliability and cost reduction.
- Investment is improved as a result of low energy and operating costs. To illustrate, it can be noted that energy management can save approximately 10% in building consumption and conservation of energy and can go up to 30% based on the occupancy.

There are a few shortfalls in BMS due to the use of traditional WSN data aggregation and routing techniques:

- There is no replacement for the battery in sensor devices as in structural monitoring and fire sensors.
- As many of the home equipments such as over, washing machines and so on are connected to AC sources and have infinite energy.
- Mobile sensors are also included in BMS when it is activated to monitor visitors.

So, the efficiency of Multi Hop Leach in BMS framework and propose a Rule Based Intelligent Multi Hop Routing for BMS framework is being researched in this study. Section 2 reviews the appropriate studies. Section 3 deals with the methodology and Section 4 discusses the experimental setup and results of the experiments. Finally, Section 5 concludes the proposed work.

Related Works

Jang et al[4] conducted a study on the way in which advanced wireless technology could be utilized by engineers in monitoring the conditions in and around buildings. A web-based data mining system was used with parameters

including data type, sensor location and time of data acquisition. It is to be noted that the proposed study demonstrated the use of wireless sensor network in monitoring buildings.

Daniel et al[5] used WSN developed from off-the-shelf components in several residential and commercial environments which is monitored with WSN deployments. The sensors which are utilized helped in monitoring components such as temperature, carbon-di-oxide concentration, relative humidity and light. The scope of deployment is the main factor along with size, layout, and space, nearly 12 to 20 nodes can be deployed and the time span of supervision was 7 to 14 days in each area. The authors demonstrated that WSN technology used as enabler for beginner ecohome scientists aided in reducing the power consumed, and at the same time with increased comfort. The feasibility of the system for business as well as resident deployment were evaluated which showed that huge data can be mitigated to useful information which is delivered to the user.

Abhilash et al[6] formed a model based on the power usage of sensor node in a multi-hop WSN, where data aggregation is used which is a method which abandons 'unnecessary' packets and saves bandwidth. Based on the user's requirements, some flexibility is designed in the protocol. The consolidated outcome showed the capability of the scheme in reducing the number of transmitted packets and the consumption of normalized energy by nodes.

Chang et al[7] used an industrial-strength WSN application for indoor environment monitoring built on tiny OS. This is widely used in South Korea and is called Control Citytrade and is harmonized with building management system. This paper discusses the use and challenges dealing with the deployment and integration of sensor network for commercial building management system including case designs as well as the total architecture of the systems.

Advanced load management strategies and techniques were studied by Nguyen et al.,[8]. Many applications are used in this particular technique. First of all, an application for heating control based on WSN is used. This study was tried and the outcomes proved that the above said technique was good in controlling heating loads and adapting to any problems which may arise in case of oscillating cost, signal from energy providers as well as distribution of system operators and so on.

Smart classroom management systems was formed as well as promoted by Chiou and Tseng[9] for improving the learning efficiency. The status of student as well as classrooms were identified through wireless sensor and this was forwarded to management systems constructed in servers. This was executed in a class at Chung Hua University, Taiwan. An initial experiment proved the efficiency of the model.

Cyber Physical System (CPS) models were proposed by Rajalakshmi[10], based on decisive server based context aware energy management systems for intelligent building. Enhancement of scalability of the system with a layered architecture in the energy management of the building was proposed. The efficiency of energy saving was increased around 30% in the context of integrating awareness into the system. After recovering investments, the real saving of energy was analysed at full-length. Every sensor and actuator in smart rooms related to state machines enabled the modeling of usage of hybridized automaton for future domain of applications.

The energy consumption in the designs of heating, cooling and ventilation (HVAC) systems were conducted at Royal Institute of Technology campus by Ahmadi et al.,[11] who found out that energy can conserved in many areas. The dynamics of temperature, humidity, as well as carbon dioxide utilizing the information gathered by sensors work was preliminarily studied. The validity of the data was verified by comparing the output of the system with limited data. The authors suggested some future studies based on the possibility of using the models obtained and fault detection and isolation techniques.

Methodology

This section explains the LEACH, Multihop LEACH and the proposed device aware multihop routing.

Low-Energy Adaptive Clustering Hierarchy (LEACH) & Multi Hop Leach: Low-Energy Adaptive Clustering Hierarchy (LEACH) signifies an energy saving protocol which comes into force when there is a failure of node in a network of the battery stops working. It is a self-organizing, adaptive technique where the sensors will organize themselves into clusters and the clusters will select their cluster head (CH) to avoid increasing energy consumption and incorporation of data aggregation thus reducing the number of messages transferred to BS thus increasing the lifetime of the network. This shows that this protocol has an effect on energy saving.

A Time Division Multiple Access (TDMA) is created and manipulated by CH which sends the collated information from node to base stations wherein the information are used by Code Division Multiple Access (CDMA). The nodes which remain are cluster members. The performance of LEACH is better than static clustering protocols by prompting nodes for volunteering to be higher-energy CH as well as the related clusters are selected on the based on the nodes which are chosen as the CH at particular point of time. In any point of time, every node possesses the task of procuring information from every node in a cluster, combining the information in obtaining a consolidation as well as transmission of the signal obtained to BS. There are two phases in LEACH protocol. They are:

CH Selection:
1. A series of nodes S is considered.
2. A number (n) between 0 is randomly selected by every node.
3. If n<R(n) then node becomes CH wherein R(n) signifies expected percent of set of nodes for final n cycles.
4. A message is sent by CH to the immediate node that it has attained the position of CH.
5. Neighbours join the CH on the basis of hop distances (signal strength).

Transmission Stage: Data is collected and aggregated by CH. Then the consolidated data is sent through single hop to BS without repetition. After some time using selection phase cluster heads are chosen.

The improved variant of LEACH is multi-hop LEACH. In this form, all sensors should aggregate data, thus increasing the overhead for sensors. Two type of communication operations are propagated by heterogenous sensor network in improving this strategy. They are inter and intracluster communications. In Multihop inter-cluster communications, every cluster should have a CH, when entire network is split into several clusters. This is to ensure communication for every node in cluster[12].

Data is got from all nodes by the CH through single-hop and the data collected is aggregated and transmitted directly to base station or via intermediary cluster head. When distance between cluster head as well as base station is huge, then cluster head utilizes intermediary cluster head in communicating to base station in case of multihop inter-cluster communication.

For networks with fixed BS, recorded data is routed in the event of multihop LEACH. The sensor node is treated as static, homogenous, as well as energy restricted. The sensors sense the environment without break and thus the information is sent at a standard rate. In sensors in which a moving source has to be overseen, these presumptions ensure it is not suitable for sensor network. This operation of multihop LEACH is divided into 2 stages: the set-up stage as well as the steady information transfer stage.

Every cluster is arranged; CH is also chosen in the set-up stage. CH is chosen on the basis of the probable percent of clustering for network as well as the quantity of times nodes were CH as of then. Decisions are made by all nodes in selecting an arbitrary number within 0-1. If it is lesser than threshold $T(n)$, node is a CH in that iteration. Threshold is established thus:

$$T(n) = \begin{cases} \dfrac{P}{1 - P(r \bmod 1/p)} & if \ \ n \in G \\ 0 & otherwise \end{cases}$$

wherein P represents the expected CH probability, r signifies the count of the current iteration, while G signifies the group of nodes which were not CHs in the previous $1/P$ iterations.

Proposed Rule Based Intelligent Multi Hop Cluster Formation: Multi-hop LEACH cannot address the node mobility of BMS – WSN model though it is heterogenous and have node mobility. Due to the larger energy consumption, traditional WSN data aggregation may not work efficiently. The location of each node is calculated and compared with the previous round in the proposed rule-based intelligent multi-hop cluster formation. Nodes running on power source are indicated by using a flag in the broadcast message. During the selection of cluster, a node with infinite energy is given priority to act as CH and all one-hop neighbors form a cluster. Nodes which are mobile have lower priority and chance of becoming CH. If device with infinite energy is not available, then the CH is selected as in M-LEACH.

Results and Discussion

Simulations were carried out using a heterogeneous environment consisting of different node count. The simulation setup and node distribution is shown in table 1. Simulations were carried out to measure number of clusters formed, average packet loss rate, and average end to end delay and percentage of non-replaceable battery nodes alive. Experiments were carried out by changing the number of nodes.

Table 1
Simulation Setup

Network size	**500 x 500 m**
Number of nodes consisting of structural monitoring / and fire alarm / Garden control real time/ Building lighting and Control/ Initial energy in Joules	200-1200 / 0.5 J
Number of nodes – Home appliances	200
Number of nodes with mobility	25

Table 2
Number of clusters formed

Number of nodes	**Multi hop LEACH**	**Proposed Device Aware Multi Hop Cluster Formation**
200	28	31
400	40	46
600	70	77
800	89	95
1000	89	103
1200	101	114

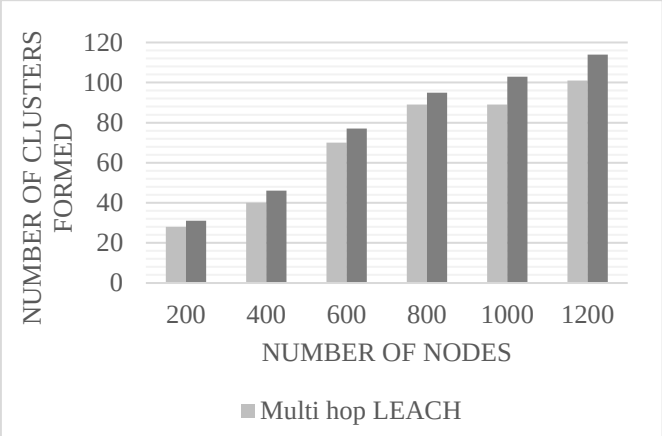

Figure 1: Number of clusters formed

Higher the number of cluster indicates smaller network subset for data aggregation leading to savings in transmission cost energy. The proposed technique increases the number of clusters formed to increase node lifetime. It can be observed from table 2 and figure 1 that the proposed method improved the number of clusters formed by 14.58% when compared with Multihop LEACH for 1000 nodes and it averagely improved 11.10% over multihop LEACH method.

Table 3
Average End to End Delay

Number of nodes	Multi hop LEACH End to End delay in Millisecond	Proposed Device Aware Multi Hop Cluster Formation End to End delay in Millisecond
200	1.76	1.7
400	1.78	1.75
600	1.961	1.87
800	29.88	27.41
1000	61.4	58.08
1200	76.84	68.3

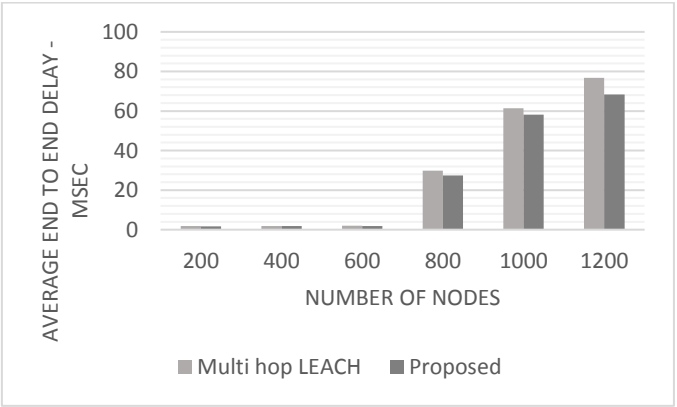

Figure 2: Average End to End Delay (sec)

It can be observed from table 3 and figure 2 that the proposed method reduced end to end delay by 11.77% when compared with Multihop LEACH for 1200 nodes and it averagely reduced 8.16% over multihop LEACH method. Table 4 and Figure 3 shows the average packet loss rate. Higher the packet loss represents the data not reaching the destination. It can be seen that as the number of nodes are increased the packet loss rate increases due to congestion. However the proposed technique reduces the packet loss rate compared to Mult Hop Leach.

Table 4
Average Packet loss rate (%)

Number of nodes	Multi hop LEACH	Proposed Device Aware Multi Hop Cluster Formation
200	8.47	7.04
400	12.61	11.15
600	13.83	11.41
800	18.63	14.29
1000	23.53	22.41
1200	24.56	20.23

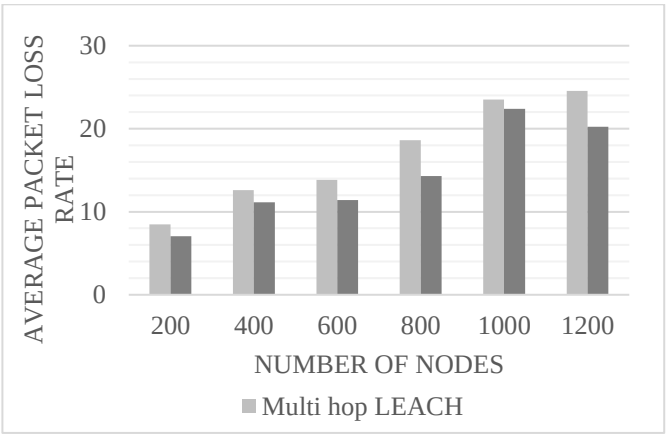

Figure 3: Average Packet loss rate (%)

It can be observed from table 4 and figure 3 that the proposed method reduced packet loss rate by 19.33% when compared with Multihop LEACH for 1200 nodes and it averagely reduced 16.05% over multihop LEACH method. The percentage of nodes alive are shown in table 5 and figure 4.

It can be observed from table 5 and figure 4 that the proposed method achieved Percentage of nodes alive by 176.47% when compared with Multihop LEACH for 700 rounds and it averagely achieved 36.02% over multihop LEACH method.

To check the efficacy of the BMS-WSN network in saving overall energy in electrical appliances, some of the nodes simulated include soil moisture sensor used in the gardens along with actuators connected to the watering system. Similarly, light dependent sensors were used to switch ON/OFF lights. The table describing the number of sensors and automatic ON/OFF switch is shown in table 6.

Table 5
Percentage of nodes alive (Non-replaceable)

Number of rounds	Multi hop LEACH	Proposed Device Aware Multi Hop Cluster Formation
0	100	100
100	100	100
200	87	100
300	74	92
400	41	76
500	22	54
600	11	44
700	2	32
800	0	19
900	0	11
1000	0	1

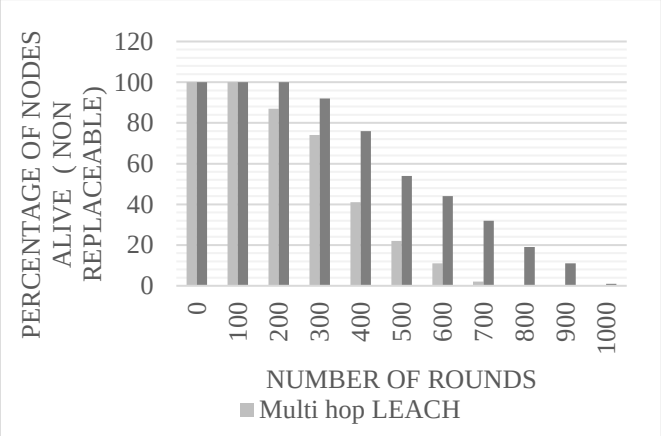

Figure 4: Percentage of nodes alive (Non-replaceable)

Table 6
The number of sensors and automatic ON/OFF switch

Number of LDR Sensors	16 outside building and 32 inside building corridor with 2 sensors in each floor
Number of Tube lights connected to the automated switch ON/OFF system	64 outside the building and 128 inside the building each of 30 watts.
Number of soil moisture sensor	4
Number of actuations connected to water sources	4

Manually if the lights are switched ON / OFF at 6 PM and 6 AM. The total power consumed by the tube lights alone is about 69 units. When the sensor system is used, it is observed that lights in the upper floor are switched off earlier along with lights on three sides of the building leading to savings of 10 units a day. This translates to 300 Units a month which is significant.

Conclusion

In the advent of inventions in the field of electronics and communication, Building Management System or automation of the buildings play an essential role in improving the service, comfort, and safety of the building in an energy-efficient manner. Indoor environment can be monitored by data sensing through wireless network. There are many drawbacks with the conventional wireless systems such as increased running cost, and large energy consumption by the monitoring devices. In the proposed technique, CH is used in the home appliances for improved energy management with non-replaceable battery. The drawback is the use of sensors with efficient mobility, as the battery that is available is higher than non-replaceable devices. The outcome is suggestive of the efficiency of the proposed system comparable with the tradition method using multi-hop routing.

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