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Efficient Resource Utilization through Sensor Virtualization

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Abstract: ***Wireless Sensor Networks (WSNs) are used in many application areas including health, agriculture and gaming. New advances in sensor technology make it pertinent to consider sharing a deployed WSN infrastructure by multiple applications, including applications which are designed after the WSN deployment. The state of the art technology can provide the opportunity to build an economic business model for application area such as smart home, health care etc. Currently building a smart home is a costly affair because of the involved infrastructure cost. In this paper we propose a VSN based business model for Smart home which supports efficient resource utilization through sensor virtualization and also minimizes the energy consumption through sensor scheduling.***

Keywords: Wireless sensor network, Virtualization, Traditional, Energy Consumption, Resources.

1. Introduction

A Wireless Sensor network is consist of large number of heterogeneous sensor nodes which are connected together in sensor network field. The position of sensor nodes need not be predetermined and this allows random deployment of sensor nodes in inaccessible terrains. Sensor nodes are fitted with an onboard processor so that they can use their processing abilities to locally carry out desired computations and transmit only the required and partially processed data to other nodes or systems. Given self processing capability of sensor nodes they are very useful in key application areas like health, military, home automation. Some of the key characteristics like rapid deployment, self organization, and fault tolerance make sensor networks a very promising candidate for military Application areas like command control, communications, computing intelligence and surveillance [1]. In healthcare area, sensor nodes can be deployed to monitor patients and assist disabled patients. Some other commercial applications include managing inventory, monitoring product quality, and Disaster Monitoring.

Up till now the real world deployments of WSNs have been tailor-made solutions where applications are bundled with a WSN at the time of deployment with no possibility for other applications to re-use the deployed WSN. Virtualization is a technique that presents physical resources logically and enables their sharing and efficient usage [2]. The new generations of sensors [3] encourage us to consider sharing them using virtualization.WSN virtualization is a relatively new field and to the best of our knowledge there is no mechanism to discover and publish WSN resources for multiple, independent applications allowing them to access these resources concurrently according to their requirements.

Virtual sensor network is composed of collaborative wireless sensor network. It is formed by a subset of sensor nodes of a wireless sensor network, where the subset is dedicated to a certain task or an application at a given time [3]. In contrast, the subset of nodes belonging to this type of network collaborates to carry out a given task at a specific time. It can be created by providing logical connectivity among collaborative sensor nodes. Nodes can be grouped into different virtual sensor networks based on the particular function they perform or task they are dedicated to. A virtual sensor is a software sensor as opposed to a physical or hardware sensor which provides indirect measurements of abstract conditions (that, by themselves, are not physically measurable) by combining sensed data from a group of heterogeneous physical sensors. For example, consider an intelligent construction site where users may desire the cranes to have safe load indicators that determine if a crane is exceeding its capacity. In this case a virtual sensor would request measurements from different physical sensors that monitor boom angle, load, telescoping length, two-block conditions, wind speed and use it for calculations to determine if the crane has exceeded its safe working load. We have surveyed the research challenges virtualization in wireless sensor network [15]. There are different types of programming techniques in virtual techniques, but we are focusing on the concept sensor virtualization in smart Home

This paper is organized as follows. Section 2 describes Concept virtualization. Section 3 explains the Problem Characterization Section 4 describes Proposed work. Section 5 describes System Implementation Section 6 describes Mathematical model. Section 7 describes Algorithm Section 8 describes the Result and Section 9 Concludes the paper.

2. Sensor Virtualization

WSN virtualization enables the sharing of a WSN infrastructure by multiple applications [4]. There are two possible approaches to WSN virtualization. The first one is to allow a subset of sensor nodes to execute an application, while at the same time (preferably) another subset of sensor nodes executes a different application [5]. These subsets can vary in size and in number according to the application requirements. The second approach is to exploit the capabilities of the individual sensor nodes and execute multiple application tasks[4], [6] and [7]. Each application task is run by a logically distinct but identical physical sensor node[11].

3. Problem Characterization

Although WSN virtualization provides efficient method to utilize individual sensor for multiple application and achieve better resource utilization, it still does not help much to improve Energy utilization.

4. Proposed Work

4.1 Resource Utilization and Energy consumption

Resource allocation in a sensor network environment refers to static or dynamic allocation of sensor nodes to the requested application. This approach is not compatible with WSNs for the lack of its storage, computing power and limited battery power. That's why comprehensive research for efficient resource utilization is needed for resource constrained physical nodes. Virtualization environment for sensors help us utilize less number of network sensors for more tasks and ultimately reduce energy consumption.

4.2. Sensor Scheduling

The sensor allocation problem arises when multiple applications are jointly trying to access single sensor but only one of the applications can contact sensor for data at any given time. This may leads to application failure due to request deadlock. We propose TDMA based approach to address this issue.

5. System Implementation

5.1 Hardware Details

Hardware component are described are as follows**.**

5.1.1. Temperature Sensor

LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature. The LM35 does not require any external calibration or trimming to provide typical accuracies of 14C at room temperature and 34C over a full 55 to +150C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35s low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. Total power consumed by the sensor 0.1KW. Features of Temperature sensor are:

1. Calibrated directly in Celsius
2. Suitable for remote applications
3. Operates from 4 to 30 volts
4. Less than 60 A current drain

5.1.2. 16 x 2 Character LCD:

Features are as follows:
1) 5 x 8 dots with cursor.
2) Built-in controller (KS 0066 or Equivalent).
3) + 5V power supply (Also available for + 3V).
4) N.V. optional for + 3V power supply.

5.1.3. 8-bit Microcontroller with 8K bytes In-System Programmable Flash AT89S52:

The AT89S52 is a low power, high performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The on-chip Flash allows the program memory to be reprogrammed in system or by a conventional nonvolatile memory programmer

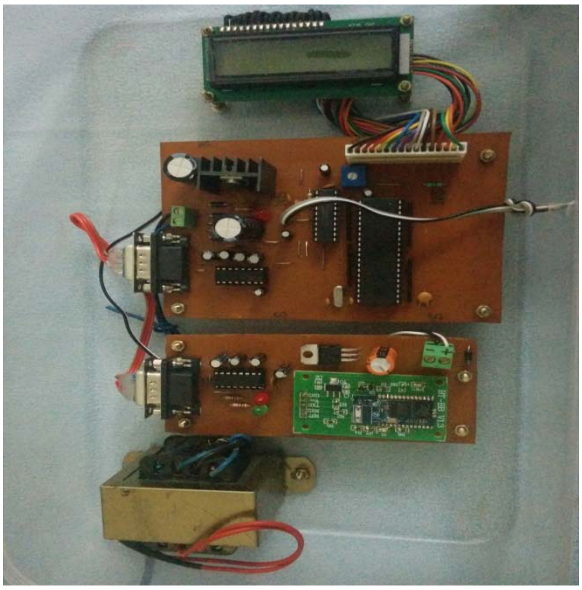

Figure 1: Hardware Unit

The AT89S52 provides the following standard features:

1) 8K bytes of Flash
2) 256 bytes of RAM
3) 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters.
4) A six-vector two level interrupt architecture, a full duplex serial port.
5) On-chip oscillator and clock circuitry.

5.2 System Architecture

Virtualization Architecture presented in figure1 is based on three basic principles. The first principle for WSN virtualization is that any new application or a service is deployed as a overlay on top of the physical WSN. The second principle suggests that any given physical sensor can execute desired task for a given application deployed in the overlay. Few of the existing sensor kits such as Java SunSpot and operating systems like Contiki support concurrent execution of multiple applications. But our project existing sensor kits runs on windows OS. and in virtual layer overall implementing in Java (Net bean 7.4)

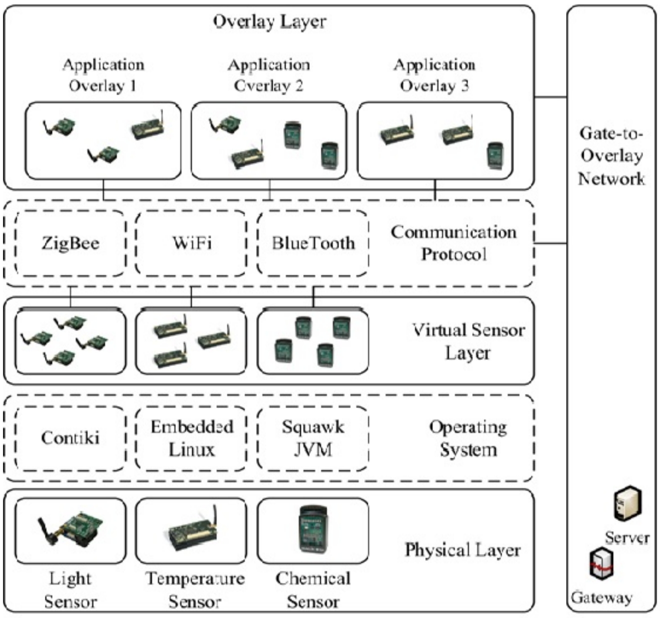

Figure 2: System architecture [7]

The third principle is that some sensor may not have enough capabilities to support the overlay middleware. In that case, they will delegate such operations to more powerful sensors and even to other nodes.

5.3 Proposed Agent Based Approach

Proposed agent based architecture is a stack of layer where each layer has defined function. The functionality of the each layer of proposed architecture discussed as follows:-

1. Physical layer

In this layer we have three types of sensor are Temperature Humidity and Sound Sensor, the main role of the temperature sensor is to read real time environment data, humidity sensor used to measured moisture in air and sound sensor is for detecting sound signal.

2. Virtual layer

The main role of this layer is to create the virtual copies of the respective physical sensors like Temperature, Humidity and Sound as per the capacity of the physical sensors.

3. Agent layer

This layer provides and manages the agent behavior. The function of this agent layer is to create, manage virtual copies and allocate it to Application as per their priority.

Implementation Details

5.3.1 Virtualization: Virtual Layer Creation as Middle Layer

Virtual instances V(i) of the underlying physical sensor are created at the virtual layer as per the request from the application. Application connects to virtual layer over WIFI and request virtual copy of the underlying sensor. Once application connects to the main system, new instance of temperature sensor will be created and assigned to the application. This instance remains locked with application until application releases it. Separate instance are created for different application requests. We have implemented two applications a. AC monitoring Application and b. Fire Alarm Application using single physical sensor node.

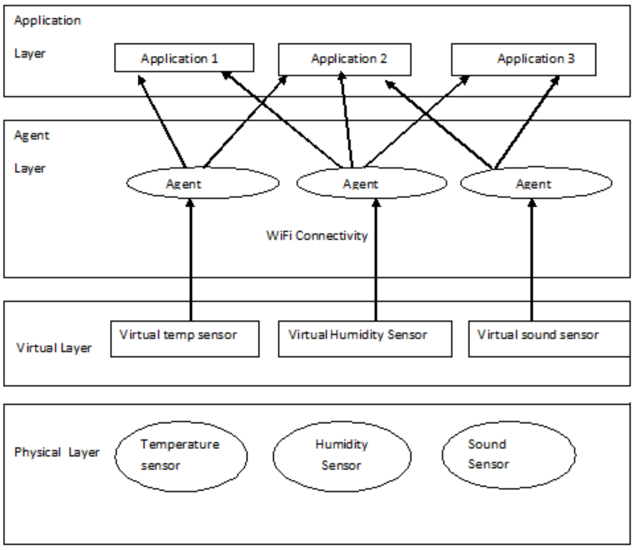

Figure 3: Proposed Architecture

5.3.1.1 AC Monitoring (ACM):

AC Monitoring application contacts to Physical sensor node via virtual layer. Virtual layer authenticates the Application request and accept it once it turns to be genuine. On accepting request it creates virtual copy of sensor node and assigns it to the AC monitoring Application. ACM will constantly connected to Sensor node as it requires data more frequently.

5.3.1.2.Fire Alarm Application (FAA):

Fire Alarm communicates to same physical sensor node via virtual Layer and requests data. A virtual copy authenticates this request as well and then allocate separate virtual copy to Fire Alarm Application so that there should be no conflict between ACM and FAA operation. Fire Alarm application will collects the temperature information from the physical sensor through the allocated virtual copy and produce an alert in case there is fire instance of in home.

5.3.2. Sensor Scheduling

Sensor scheduling is basically a sensor selection or sensor management, and its concerns with turning on the right sensors at the right time to achieve desirable performance with minimal energy consumption.

To achieve effective scheduling we are using TDMA based model combined with priority ranking where different applications are allowed to use sensor for assigned time slot as long as its priority is recognized at the given time. In our case ACM is low priority (P3) ranked application where FAA has got P1 priority ranking. ACM will keep occupying the time slot and keep using sensor as long as another high priority ranked application request that time slot. If at any given time Fire Alarm Application requests data from sensor, ACM will release time slot for Fire Alarm application.

5.3.3 Energy Utilization

In our case since ACM is low priority application, we assume it need not be connected to sensor all the time. So we will decrease the number of time it communicates to sensor for data. Sensor will keep switching between sleep mode and Active mode as per incoming request. So ACM will contact sensor for data with given time slot T(s), where s = time in second. T(s) will be in sync with the Sensor active mode interval AI(y).Sensor will be in sleep mode and active mode for respective time intervals SI(x) and AI(y). Sleep mode switching will help us save energy consumption of sensor node. Once SI(x) is over, sensor will switch to Active mode and will provide data to ACM for AI(y) time.

6. Mathematical Model

6.1 Resource allocation

Residual resources management is performed by measuring the available remaining resources after utilization. We have given the mathematical formulation of the remaining resources of sensor node, corresponding virtual copies, and its storage. the residual capacity of the sensor nodes is defined as the total processing capacity of the sensor nodes which is given by

Rn = { cap(s) [Tn] } - Un
Un – Utilization of sensor node
Un = { cap(s) }* (Vc) }

6.2 NP-hard and NP-Complete Analysis

The proposed work comes into the NP complete because in particular time it will give the result. In this case we assume that we have virtual sensors and every application uses one virtual sensor. A virtual sensor means we have created multiple instance of the same physical sensor. So one sensor cannot process multiple applications at the same time. For that we are using Time Slots. A time slot will be allotted to every newly created Virtual Instance.

No. of Virtual Sensor = No. of Application
So now during Time Period T only One Virtual Instance will be active and the same will be utilizing the energy of the physical sensor. After time T the second Instance now become active and the same will now utilize the energy of the sensor. This continues same for all the Virtual Instance. Now in Round Robin fashion the system continues the process from the first Virtual Instance. It's clear that at a time only one Application uses the physical senor. The time cycles move fast which gives an illustration of virtual instances. It looks like that we have multiple sensor for multiple application. But in practical we have only one sensor.

7. Algorithm

7.1 Resource Allocation Algorithm

Step 1. Authenticate incoming request R(Ai)
Step 2. Check the priority of the application Request
P(Ai) if P(Ai) > P(Ci)
Go to Step 6.
Where P(Ai) is Priority of New Application request
And P(Ci) is Priority of current Application
else Go step 3.
Step 3. If P(Ai) < = P(Ci), Check if Virtual copy is available if Yes then assign it to R(Ai) with time slot T(s) and Go to Step 8
else Go to Step 4
Step 4. If Virtual Copy not available, check if Virtual Copy can be created if Yes, create virtual copy and assign it to R(Ai) with Time slot T(s) else go to Step 5.
Step 5. Reject R(Ai) and Go to Step 8
Step 6. Check virtual copy availability and assign it to R(Ai)
Step 7. If Virtual Copy is not available create new Virtual copy V(i) and allocate it to R(Ai)
Step 8. Exit

8. Result

We compared the utilization of number of sensor nodes against multiple applications by using WSN and VSN approach. In case of VSN we were able to use single sensor node for multiple application by using virtual instance of physical sensor, thus avoiding need of adding extra sensor for each newly added application to infrastructure. While in case of WSN we were restricted to use single sensor for single Application thus increasing the cost of the application. Below graph shows the comparison of WSN and VSN and explains how VSN help us reduce the cost of the infrastructure by utilizing single sensor for multiple applications.

Table 1: Comparison of traditional VS Virtualized approach

	No of sensors	*Applications served*	*Resource utilization (%)*	*Energy Consumption (KW)*
Traditional approach	3	3	100%	1.4 KW
Virtualized approach	3	9	300%	0.577 KW

Figure 2 shows the comparison of Resource utilization in traditional approach and virtualization approach. Virtualization approach shows 30% better utilization of sensor while serving same number of applications. Figure 3 shows the energy consumption graph with and without sensor scheduling. With the help of scheduling sensor showed less energy consumption than earlier system serving same number of applications.

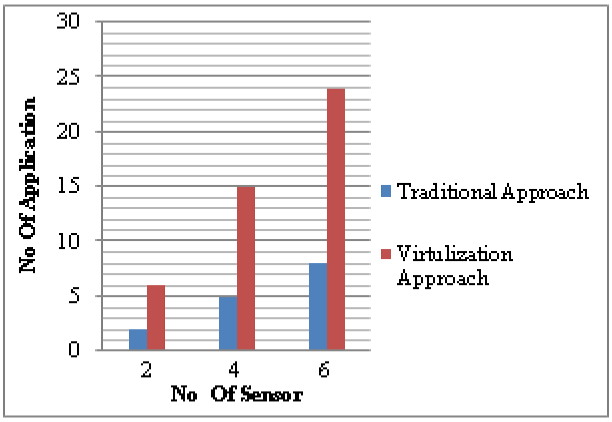

Figure 2: Resource Utilization

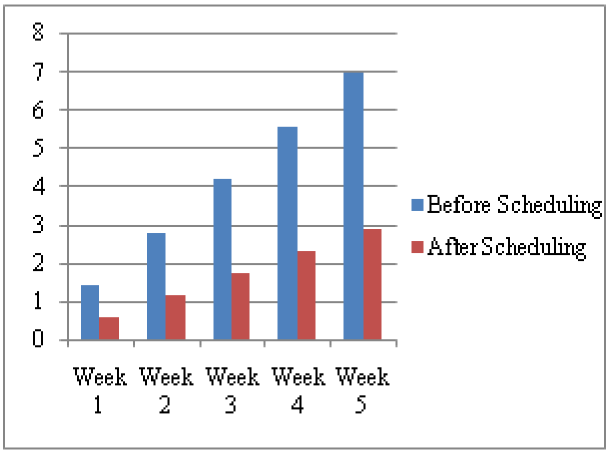

Figure 3: Energy Consumption

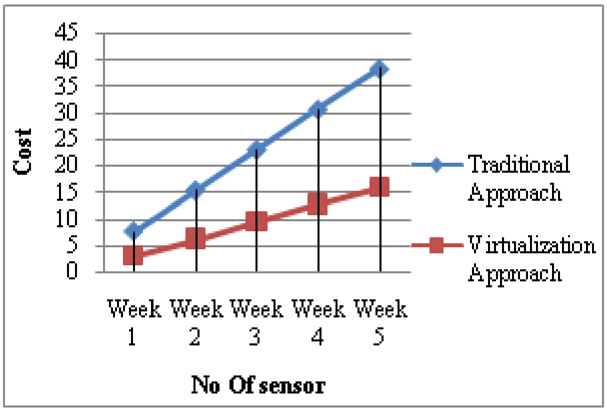

Figure 4: Cost of traditional versus virtualization approach

Figure 4 shows the cost of traditional approach against the virtualization approach with the help of scheduling we can found that Virtualization approach minimizes the cost compared to the traditional approach significantly for the two applications.

9. Conclusion

In this paper, we presented virtualization approach in wireless sensor network concerning its application in smart home. By allowing multiple heterogeneous nodes in different sensor network architecture to coexist on a shared physical substrate, virtualization approach may provide flexibility, promote diversity, ensure security, and increase manageability for smart home applications. Here, we propose a business model of smart home based on VSN, mathematical model for resource allocation and measurement and evaluate the model for smart home implementation. With the help of virtualization and sensor scheduling we have to improved resource utilization as well minimizing the energy consumption so that smart home cost would be reduced.

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