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# Role of Sensor Virtualization in Wireless Sensor Networks

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***Abstract* —Wireless sensor networks (WSNs) are widely used in many real life applications due its pool of operating advantages. Such networks are mainly used for the applications like health monitoring, industrial automation, smart home monitoring, military applications etc. These applications requires heterogeneous type of WSNs. The small scale WSNs can be easily deployed for such applications, however same becomes complex for the larger scale WSNs. This is because of the restricted control of administrator over the communication barriers, WSN domains and cost estimations from the different Sensor vendors. To overcome this constraint we need to have more cost effective and flexible solution which enable easy and real time deployment of heterogeneous networks. This is achieved by using the concept of virtualization in WSN. The virtualization of sensor network allows the sensor nodes to coexist over the common physical sensor substrate. This method provides cost effective solutions, flexibility and requires less time for deployment. Virtualization also provides added advantages like security, improved management, promoting diversity etc. In this paper our main aim is to introduce WSN in detail, concept of virtualization in WSN and its design.**

***Keywords* — Wireless sensor networks, WSN, sensor nodes, heterogeneous sensor networks, virtualization, VSN, cost, vendor**.

## I. INTRODUCTION

Now a day's WSNs are frequently used for large scale real time applications such as tracking/monitoring industrial automation manufacturing process; environmental monitoring like pollution monitoring in city areas; real life examples of using such networks are smart home automation, health monitoring applications. But such networks are basically build to provide services to single application [1]. In such cases the collected information in such networks is commonly present with one authority which is nothing but the owner of this network. The limitation of such approach is that, the use of resources is not efficient enough and does not allow building of new applications by using the existing sensing infrastructure. This problem becomes more and more critical when the application requires large scale WSN deployment in less time. In that case cost of resources, admin restrictions become more complex to manage. Other problems of WSNs is, its design of single application and single user which resulted into high cost and more efforts on its deployment. One real time example of such approach is the camera deployment on the UK motorways and roads. This involves various authorities such as highway agency, police, and local city of authorities etc. [2] deploying their own network of cameras for covering same physically area. This involves three times costs of deployment of same network over the same area. To avoid such problem of large scale WSN deployment in more cost effective manner, new solution is proposed i.e. virtualization in wireless sensor networks.

The process of virtualization is the approach which presents physical resources logically and then allows end users to share it and use it efficiently [3]. The current generations of such wireless sensor networks motivates the researchers to work on them using new virtualization techniques. Virtualization in WSN is currently new research field and still to the date there is not much work done on discovering and publishing the resources of WSN for multiple applications. In this review paper our main aim is to explain the concepts of Homogenous and Heterogeneous WSNs in detail, their comparative analysis and overview of virtual sensor network protocol architecture

## II. DETAILS OF WSN

In this section we discuss different types of wireless sensor networks such as homogenous WSN and heterogeneous WSN.

### *A. Homogeneous WSN*

In Homogeneous network all the deployed nodes are identical in terms of hardware complexity and battery energy. With static clustering (cluster heads once selected, serve for the entire lifetime of the network) implementation in a homogeneous network, it is clear that the cluster head nodes will be overloaded with the long range transmissions to the remote base station, and extra processing is required for data aggregation and protocol co-ordination. This makes cluster head node expire earlier than other nodes. Considering this situation it is necessary to ensure that battery of all the nodes expires at about the same time, so that very little energy is wasted when the system expires. One of the way to ensure this, is to rotate the role of a cluster head randomly and periodically over all the nodes as proposed in LEACH [4]. But the downside of using role rotation in homogeneous is that all the nodes in homogeneous network will be expected to be capable of acting as cluster node which demands superior hardware capability and in turn increases cost of the infrastructure.

*B. Heterogeneous WSN*

Heterogeneous sensor network uses different types of nodes with different battery energy and functionality to tackle the challenge of cluster head node. The main goal is to embed complex hardware and extra battery energy for fewer cluster head nodes, thereby reducing the hardware cost of the rest of the network. But fixing the cluster head nodes means Role rotation is no longer possible. Nodes that are deployed farthest from the cluster heads will always spend more energy than the nodes that are closer to the cluster heads. On the other hand when nodes use multi-hopping to reach the cluster head, nodes which are closest to cluster head have the highest energy burden due to relaying. This results in non-uniform energy drainage pattern in the network [4].

Given the above details none of the network topology can achieve all desirable network characteristics such as low hardware cost, uniform energy drainage etc. Homogeneous WSN supports uniform energy draining by using Leach Protocol while heterogeneous networks achieves lower hardware cost.

## III. APPLICATION AREAS OF WSN

Sensor networks may formed of different types of sensors such as seismic, magnetic, thermal, visual, infrared, acoustic, radar, which are able to monitor a wide variety of ambient conditions that include following temperature, humidity, vehicular movement, lightning condition, pressure, soil makeup, noise levels, presence or absence of certain kinds of objects, mechanical stress levels on attached objects. Sensor nodes can be used for continuous sensing, event detection, event ID, location sensing, and local control of actuators. This concept of micro-sensing and wireless connection of nodes is promising for many new application areas like military, environment, health, home and other commercial areas [6].

*A. Health applications*

Health applications utilising the sensor network capability includes integrated patient monitoring system, diagnostics, drug administration in hospitals, Tele monitoring of human physiological data etc. One of the promising capabilities of WSN is the ability to create wearable and implantable body area networks.

*1)Tele-monitoring of Human Physiological Data*: One of the benefit here is that the physiological data collected by sensor networks can be stored for a longer period of time, and can be made available for medical investigations as and when required. In addition to this, same installed sensors can also monitor and detect the behavior of elderly people.

*B. Home applications*

As technology advanced smart sensor nodes and actuators are fitted in appliances such as vacuum cleaners, microwave ovens, refrigerators, and VCRs [6]. These sensor nodes sitting inside the domestic devices can interact with each other and with the external network via the Internet, Satellite or other such wireless medium. This enable end users to manage home devices locally and remotely with more convenience.

*1)Smart environment:* The design of smart environment may have two different approaches, i.e., technology centric and human centric [6]. For technology centric environment, new hardware technologies, better networking solutions, and redefined middleware services have to be developed. While for human centric, smart environment has to adopt to the needs of the end users in terms of input output capabilities. Sensor nodes can be used to create a smart environment by embedding them into home furniture, appliances, and they can communicate with each other and the main room server [6]. Same way room servers can also communicate with other room servers to learn about the services they offer. These room servers and sensor nodes integrated with existing embedded devices become self-organizing, self-regulated, and adaptive systems based on control theory models as described in [6],[7].The computing and sensing in this environment has to be persistent, transparent and reliable.

*C. Military applications*

Wireless sensor networks can be an utilised in different military application areas like command, control, communications, computing, intelligence, surveillance systems etc. The quick deployment, self-organizing and fault tolerance characteristics of sensor networks make them a very promising candidate for military Applications. As sensor networks are formed by dense deployment of low cost disposable sensor nodes, destruction of some nodes by hostile actions does not affect a military operation as compared to the destruction of a traditional sensor. This makes sensor networks concept a better fit for the battlefields. Some of the military applications of sensor networks are battlefield surveillance; tracking and monitoring of ground forces, equipment and ammunition; reconnaissance of opposing forces and terrain targeting; nuclear, biological and chemical (NBC) attack detection and reconnaissance.

*1)Monitoring friendly forces, equipment and ammunition:* Sensor Networks can help Military commanders constantly monitor the status of friendly troops, condition and availability of equipment and ammunition in a battlefield. Small sensors attached to troops, vehicle, equipment and critical ammunition can report the status of those elements. These reports are gathered in sink nodes and sent in real time to the troop leaders to help them in decision making [6].

*D. Environmental applications*

Some environmental applications of sensor network include tracking the movements of birds, small animals, and insects; monitoring environmental conditions that affect crops and livestock; irrigation; macro-instruments for monitoring of large scale earth and planetary exploration; Chemical & biological detection, Precision agriculture; Earth, and environmental monitoring in marine, soil, and atmospheric contexts; Forest fire detection; Meteorological or geophysical research, Flood detection etc.

*1)Forest fire detection*: Sensor nodes can be deployed strategically, randomly, and densely in a forest and can relay the exact origin of the fire to the end users before fire spreads uncontrollably. Millions of sensor nodes can be deployed and integrated using effective radio frequencies. In this case, as sensor nodes on the field may go unattended for months and years, they are equipped with effective long lasting power source like solar cells or other such battery. Sensor nodes will collaborate with each other over wireless communication medium to perform distributed sensing tasks and won't be affected by the obstacles such as trees and rocks which is not the case with wired sensors.

*2)Flood detection:* An example of flood detection is the ALERT system [9] deployed in the US. Several types of sensors like rainfall detection, water level indicator, weather monitoring are deployed in the ALERT system. These sensors provide information to the centralized database system in a pre-defined manner. Research projects, such as the COUGAR Device Database Project at Cornell University [9] and the Data Space project at Rutgers [9], are investigating distributed approaches in interacting with sensor nodes in the sensor field to provide snapshot and long-running queries [10].

## IV. METHODOLOGY

Virtualization, in computing, refers to the act of creating a virtual (instead of actual) version of something, including but not limited to a virtual computer hardware platform, operating system (OS), storage device, or computer network resources.

The term "virtualization" traces its roots back to 1960s mainframes, during which it was a method of logically dividing the mainframes resources for different applications. Virtualization has started gaining more attention in computing and networking because of its benefits like efficient resource utilization, lower cost, increased flexibility, manageability and interoperability among different computing devices. With the above benefits, virtualization in WSNs is playing key role in realization of the Internet of Things. Research efforts in sensor networks virtualization are mainly focused around OS virtualization, sensor virtualization, network virtualization, virtual machines and middleware layers. Running multiple OS at node level has proved least inefficient due to constraints in sensor hardware. Moreover, running one or more applications that are not supported by the host OS isn't practised much in sensor nodes as compared to the PCs which has restricted it from taking advantage of full platform virtualization. To date most of the available OSs are developed using event-driven framework (e.g., TinyOS, Contiki). A thread-based approach is supported by the kernel of the MANTIS OS. Platform virtualization with a node running distinct host and guest OS threads has been demonstrated by the TinyMOS implementation which can run a typical TinyOS program as a MANTIS thread. Sensor virtualization is supported by inserting an abstraction layer between the application Logic and the sensor driver to address issues like incomplete a priori knowledge of the area of operation, recalibration of sensing equipment, changing conditions, etc. A component targeting sensor virtualization, which is runtime programmable and is able to execute different adaptation schemes that may change during the application lifetime, is presented in [11], [12], [13].

Another area of research on virtual sensors is related to assumption when a physical sensor of the WSN does not work anymore. In this context, the study of [11] presents a method where virtual sensors infer approximation values using fuzzy logic rules with the assumption that physical quantities sensed by neighbour sensors are related. Network virtualization in WSNs focuses on algorithms and protocol support for the formation, usage, adaptation, and maintenance of dynamically varying subset of sensors collaborating on specific tasks and being organized as a VSN using resources of a shared physical infrastructure. These nodes are dependent on those outside the subset to achieve connectivity and overcome the deployment and resource constraints. To make VSNs a reality, a number of mechanisms for VSN maintenance (e.g., adding/deleting nodes, entry/exit for VSN, and merging/splitting of VSNs) and membership maintenance (e.g. dynamic assignment of sensor roles) must be developed. A mechanism for self-organization of VSN members relying on a cluster tree-based scheme is presented in [11].Virtual machines are currently used in high end servers and personal computers for various purposes such as platform independence and isolation. But in case of sensor networks, focus is on re-programmability, i.e., the capability of dynamic injection of new code into each node on site. Examples of stack-oriented virtual machines include Mate and ASVM [14],[15]. Their goal is to provide an application-centric virtual machine that provides much needed flexibility to support a safe and efficient programming environment. By providing a limited number of instructions necessary for a specific application, Mate/ASVM can reduce the size of the assembly code to be transmitted to each node. Melete extends Mate and supports multiple concurrent applications. VMSTAR[16] is another framework for building application specific virtual machines that allows the dynamic update of the system software, such as the virtual machine, as well as the application code.

In the last few years, many varying middleware solutions for WSNs have been presented and their architectures have been influenced by the progressive shift of application paradigms from targeting single sensor networks towards implementing the Internet of Things, where applications will operate over multiple interconnected networks on a global scale. Each middleware solution creates its own architectural design assumptions that are largely based on the application domain it aims to support. Thus, each solution provides different degree of support for features of virtualization such as resource and service discovery, collaboration of heterogeneous nodes, interconnection of sensor sub-networks, connectivity to external networks, ease of deployment and maintenance, concurrent execution of multiple applications, scalability, adaptability, and reliability. Most of the current solutions try to facilitate high-level querying of sensor data, help to mask the distribution and heterogeneity in the sensor network, and address resource constraints by providing energy-aware routing and query processing.

## V. VIRTUALIZATION ARCHITECTURE IN WSN

A Virtual Sensor Network is formed by a subset of sensor nodes of a WSN where subset is dedicated to a certain task or an application at a given time [17]. In WSN, all the nodes in the network collaborate more or less as equal partners to achieve the goal of sensor deployment. In contrast, the subset of nodes belonging to the VSN collaborates to carry out a given task at specific time. This makes VSN depend on the remaining nodes to provide VSN support functionality to create, maintain and operate. In the proposed approach, multiple VSNs may exist simultaneously on a physical wireless sensor network, and the membership of a VSN may change over time. As the nodes in a VSN may be distributed over the physical network, they may not be able to communicate directly with each other. In Figure 1, two Virtual Sensor Networks coexist over the same physical sensor network infrastructure[18].

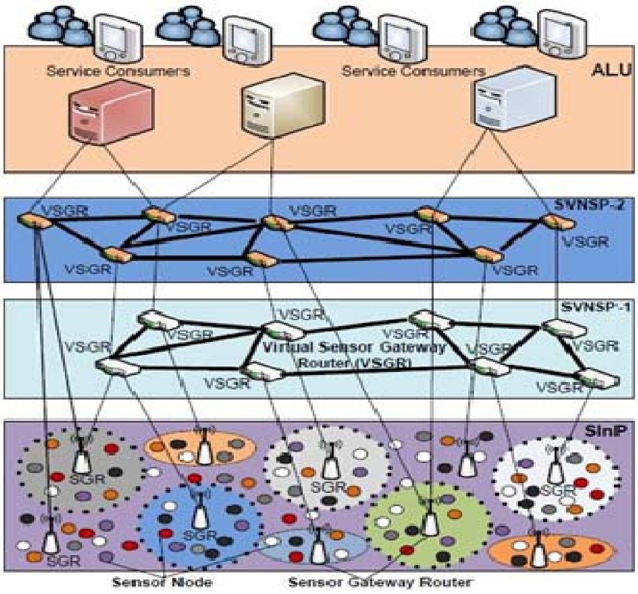


Fig 1: Virtual sensor network architecture [17]

*A. VSN Protocol Architecture*: In WSN, infrastructure provider and service provider are the same entity. However, increasing demand of WSN in different state-of-the-art-technology applications makes it necessary to differentiate between the roles of WSN infrastructure providers and service providers. The objective behind this is to minimize the establishment and manageability cost. The main difference between the participants in the sensor network virtualization model and the traditional model is the presence of two different roles, SInP and SVNSP, as opposed to the WSN provider as a whole. In the proposed architecture, VSN environment is a collection of multiple heterogeneous sensor networks coming from different SInP. Each SVNSP requests resources from one or more SInPs to form VSN, and deploy customized protocol and services over the hired VSN resources [17].

*B. Sensor Infrastructure Provider (SInP)*: SInP deploys and manages the substrate physical sensor network resources in the field. These includes different types of sensor nodes. Of these sensor nodes there are few sensor gateway routers (SGR) that act as the sink node. All SGR has got enough power supply and other resources such as memory and computing power [17] and all are connected through the high speed wireless network. Different Virtual Sensor Gateway Router (VSGR) can be hosted on single SGR and offer their resources through programmable interfaces to different SVNSP. SInPs distinguish themselves through type of service they provide. Various vendor companies can deploy sensor node and create their individual infrastructure, which can be used by the company itself or can be rented to different virtual service providers to run their individual application. This helps the effective utilization of physical sensor node in a large scale sensor network. Figure 1. Shows Virtual sensor network created by different type of sensor nodes deployed by different companies. Services can be made available to the consumer through virtual sensor gateway router.

*C. Sensor Virtualization Network Service Provider (SVNSP):* SVNSP leases resources like processing power, memory and bandwidth from multiple SInPs to create and deploy VSN. In Figure 1, there are two SVNSP: SVNSP-1 and SVNSP-2 which consists of leased resources from SInP and provides different types of virtual network services to the service consumers. The virtual link used between the two VSGR are also the leased wireless link from SInP. An SVNSP can provide network services to multiple SVNSPs and it can be used in a recursive way [17].

*D. Application Level User (ALU):* ALU in VSN architecture are similar to those of the existing WSN, except that the existence of multiple SVNSPs from competing SInPs provides a wide range of choices. End user can connect to multiple VSNs coming from different SInP for multiple applications. In Figure 1, service consumer uses different types of ALU interface. VSN hides SInP complexity from the service level consumers by defining clear abstract layer [17].

## VI. CONCLUSION

In this paper we have presented the review of wireless sensor networks and need of virtualization in WSN. Existing techniques of WSN deployment does not allow single node to be used for multiple application at a given time. Implementation of virtualization in sensor network enable WSN to share resource across applications and reduces cost, time required, management efforts etc. This has become interesting research area for WSN future studies. Our future interest is to build a system which uses concept of virtualization to enables single sensor to be utilized by the multiple application.

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