Middleware Framework for Network Virtualization in SHAAL

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Abstract*— Wireless Sensor Network (WSN) has led to a new paradigm of Internet of Things (IoT). WSNs are usually deployed for a particular application. However, the demand of WSNs in Smart Home and Ambient Assisted Living (SHAAL) is the accumulation and allocation of multiple resources providing diverse services and applications. Virtualization of a sensor network is an emerging technique that permits aggregation of several independent heterogeneous sensor networks. The technique of virtualization poses overhead challenges like more processing and power consumption. In this paper efforts have been put forward by proposing an energy aware middleware framework that resides on the sensor nodes to achieve network virtualization for SHAAL.

Keywords*— Wireless Sensor Network (WSN), SHAAL, Virtual Sensor Networks (VSN), Middleware.

I. Introduction

Advancement in medicine, food production, ease of life and living standards getting higher are one of the key factors that contribute to a longer and healthier living, as compared to the previous generations. In fact, roughly about 20% of the world's population will be age 60 or older by 2050 [1],[2]. An increase in age brings its self with several contests to the elders due to their cognitive decay and age-related diseases, along with limitations on the physical activities like movement and hearing. There will be a rise in the health care costs as caregivers and clinicians will have to spend more time in taking care of elderly people. Therefore, the current model of caring is going to be strained as the aging population increases in the next few years.

To cater this problem, SHAAL contributes in the health care domain it is facilitated by the significant developments in the field WSN, middleware design, M2M communications, IoT and now virtualization of sensor networks and embedded devices [3]. One of the dynamic fields of remote sensing and observing is wireless sensor networks. Classical sensor networks are intended for a specific application like light control or temperature, this approach will not fulfill the requirements of SHAAL where multiple applications with diverse desires like heartbeat, blood pressure sensing, surveillance and fall detection have to aggregate for the health monitoring. The future of SHAAL lies in a system design that must have the ability of handling the multiple infrastructure providers with diverse sensing nodes and service providers combining on a platform to facilitate elders at home.

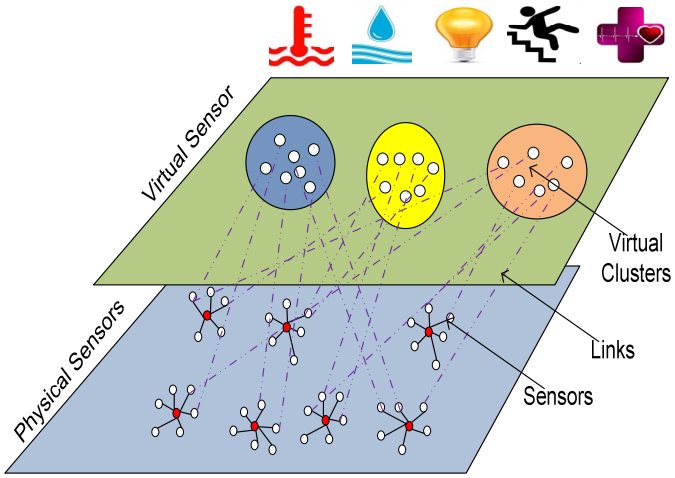

Fig. 1 General architecture of virtualization

To come up to the expectations there is an emerging concept of wireless sensor network virtualization. It is a promising method that enables multiple applications to run on a single infrastructure or multiple infrastructures serving different service providers by separating the application layer from the underneath communication layers. Furthermore, virtualization allows efficient management of sensor network resources by dividing a single network into different sub sensor networks including support for the nodes to join or leave cluster according to the situation.

Although, the recent efforts in the field of WSNs virtualization by [4-10] are cheering however, the challenges of efficient management, sharing, and utilization of the resources in an energy aware manner is still demanding. There is a need of a middleware design for SHAAL that focuses on the overall application management on different networks, while increasing the network longevity. The paper proposes a novel middleware framework for SHAAL that tackles both the multiple applications management at the node level and management of the virtual networks of sensors in an energy

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aware manner at the node. The whole middleware resides at the node.

The remainder of the article is organized as follows. Section II presents the related work, while section III elaborates the generic model of virtualization. Section IV shows the proposed middleware framework, components of middleware, and session establishment. Finally, section V concludes the paper.

II. Related Work

Virtualization of a sensor network is a concept that has two main goals sensor virtualization and network virtualization. There have been a number of efforts in the literature regarding virtualization of the sensor networks that is collaborative sensing and transmission by a subset of WSNs with a few sensors dedicated to one task and few dedicated to other tasks at a given time [11]. Moreover, sensor virtualization is running multiple tasks on a single sensor. These properties can be achieved adding an abstraction layer that decouples the sensor nodes from the applications.

The middleware layer is one of the most predominant areas for achieving full platform virtualization [4]. A number of middleware frameworks are presented in the literature in which there are two main classifications of the middleware; a class that provides the programming abstraction and the other class providing programming support. Further classifying programming support approach into the database-inspired approach, event-based or message oriented approach, modular based approach, application based and virtual machine based approach [12]. The virtual machine based approach is the closest approach that facilitates multiplications on a single node and the most pioneer work in this regard is Mate [13] that supports sensor virtualization, further its work was carried forward by Melete [14] that added dynamic collaboration of nodes to provide network virtualization. In the last few years a number of projects have been launched based on middleware targeting IoT, with the aim to provide a platform for multiple interconnected networks to collaborate.

The authors of VITRO in reference [4] provide a service provisioning framework for virtualization of the sensor network. Virtual sensor network manager a component of the framework lies at the core network and a powerful gateway managing all the virtual sensor networks allowing different service providers and infrastructure providers to collaborate in achieving the customer requirements in a seamless manner.

A framework supporting both sensor virtualization and network virtualization is proposed in SenShare [9] by running multiple concurrent application, it provides an in node hardware abstraction layer that decouples the hardware from the sensor node. An application running on SenShare can span across whole network or selected subset of the physical network. Dynamic subsets of the sensor network are constructed through an overlay topology. However, it is not energy aware and its design causes overhead in memory usage and processing.

A smart home model presented by the authors in [15] provides a global picture of different infrastructure providers and service providers how they can collaborate with each other applying the concept of virtualization. Middleware The main controlling hub of the network lies in the sensor gateway router that is based on embedded Linux responsible for managing multiple applications and networks. It also provides the business model for future virtual sensor networks. It poses less memory and processing overhead but without considering the holistic energy usage of the sensor networks.

Authors in [8] propose a multi-layer architecture that takes into account network virtualization of heterogeneous sensor nodes, where powerful nodes taking more burden of the network allowing devices with less capabilities to just perform the primary task of sensing. Servilla [10] only considers sensor virtualization, by running multiple applications and services on heterogeneous sensor nodes.

Project of I-Living in [6] proposed multi radios framework with respect to use all of the resources for the assistance of elderly people at home however, it doesn't incorporate the sensor virtualization to assist elderly people. The research articles in literature try to fully virtualize the sensors and sensor networks. Lowering overall power consumption has to be given priority in the middleware design for virtual sensor networks. The novel middleware framework proposed in this article considers both network virtualization and sensor virtualization in an energy efficient manner, such that the sensor network longevity is increased and power consumption is minimized.

III. Generic ModeL

Sensor networks have usually been studied in application specific areas but for all sensors to collaborate on a platform to be a reality researchers have to come up with system designs that have the capabilities of combining all the sensors with different nature and specifications with respect to the properties like power consumption, processing time, memory and transmission range. Sensor networks are required to dynamically collaborate and facilitate different applications on runtime, sensor networks forming groups as shown in fig.1. It facilitates a number of infrastructure providers and service providers to combine together supporting each other's interest and facilitating the user at the maximum.

In virtual sensor networks virtualization layer combines different physical sensors to facilitate a number of applications simultaneously like temperature, humidity, light and health care sensors satisfying user queries. Virtual sensor network's middleware decouples the applications from the specific hardware and networks. Such as the applications are blind to the hardware they are using.

In case, if some elder falls down or in some critical health condition, all-out resources are to be allocated to health care applications facilitating the health sufferer by combining all the underlying sensor networks.

IV. Proposed Middleware Framework

The proposed framework focuses on the challenges regarding efficient network management to support multiple applications for SHAAL while keeping an eye on the power

requirements of the whole network that monitors the everyday activity of the elderly or dependent persons at home. The goal of the proposed middleware is to improve the overall lifetime of the sensor network.

The proposed framework is crafted in such a way that it sums all of the heterogeneous devices on a platform where their services can be shared in energy efficient. Fig.1 shows mixed sensor devices at the lower layer. The second layer in the diagram is the virtual sensor layer where all the logical instances of the physical sensors are present. Furthermore, each sensor can have multiple instances. The proposed framework is designed to react to the changes in the environment and to a single node to adapt its behavior according to different applications and situation needs.

The proposed framework separates the sensor node from the applications in such a way that the application is un aware of which set of sensor or group of sensors will be used to facilitate it and sensor no longer knows which part of user application it is running. The major challenges in this scenario are how applications will find the sensor, how they will request for resources in an energy efficient manner and lastly the safekeeping of data, that which sensor is to be or not to be used for certain applications and users. For example, private heartbeat monitoring of a person at home should never be used to facilitate any application from strangers apart from, the clinician.

In the proposed framework, the above challenges are tackled by the middleware modules a single application can be distributed over a number of virtual sensors, where a single sensor is capable of emulating a number of virtual sensors. Moreover, the sharing of the infrastructure is made possible by an abstraction layer that resides at each sensor node. The virtual manager i.e. the core of middleware design has to make sure that the groups of the sensor nodes are made dynamically according to the happenings and the application requirements. Furthermore, the outline is designed to react to the changes in the environment and to adapt its behavior according to different situations. Few of the characteristics of the proposed middleware framework are:

- More energy consuming tasks like video processing are to be performed by the powerful sensor node or group of nodes
- In multi radio option use of less power consuming protocol is to be chosen, but if situation demands high data rate not to compromise on the QoS.
- Virtualizing the sensor network and by combining weak and strong sensor nodes to carry a particular application task according to the energy matrix of the network
- Increase the sleep time of the sensor nodes especially for those sensors consuming more energy (Video capturing) to extend the lifetime of the network

service oriented architecture is used that is a modular approach to facilitates multiple services with same sensor output it is an effective technique of reducing the overall network transmissions caused by the redundant data requests by the applications

A. Components of Node Middleware

The key modules of the middleware are shown in Fig.2. The service discovery component is responsible for updating the services offered by the sensor nodes.

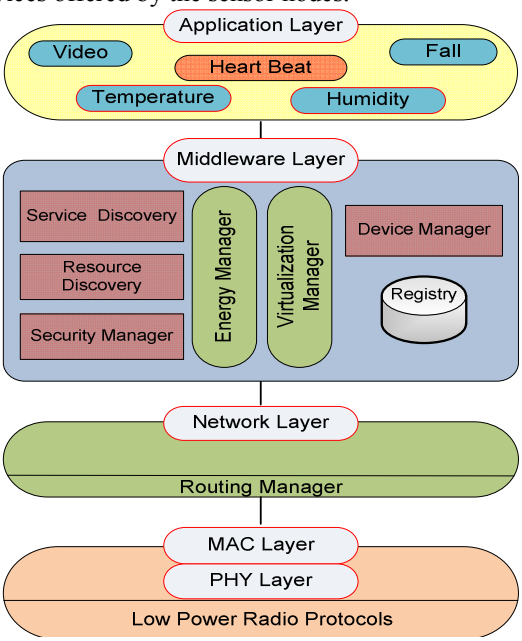

Fig. 2 Middleware virtualization architecture

Resource discovery updates the resources available that is sensor added or removed from the network. Security manager component makes sure that the data is accessed by the authenticated users. Device manager is to control hardware and software fault detection tempering on sensor the nodes and uncertain sensor data reading. One of the significant components of the proposed middleware is the virtualization manager it manages the virtual networks. Furthermore, middleware collaborates with the resource manager and energy manager to manage the network. All the decisions taken by the virtualization manager are based upon the energy manager.

Energy manager acquires energy parameters of the sensors available. Energy manager keeps a record of all the sensors' lifetime parameters and virtualization manager estimates how long a particular sensor or a group of sensors can facilitate applications. Virtual sensors networks are molded according to the input provided by the. Furthermore, the virtualization manager sets the frequency of the sensing and transmission of data according to the application priority, available resources and the energy parameter of the nodes.

B. Node Architecture

The entire home sensor nodes connect to the sink node that are capable of accepting data from different protocol standards

and pass them to the remote server. Sink node is responsible for publishing, negotiation, provisioning, discovering, managing, and virtualizing the sensor network.

Energy manager also resides at the sink and the entire network is managed by the middleware having a closer look on the current network energy parameters. The middleware framework that resides at the node takes into account both the network virtualization and the sensor node virtualization.

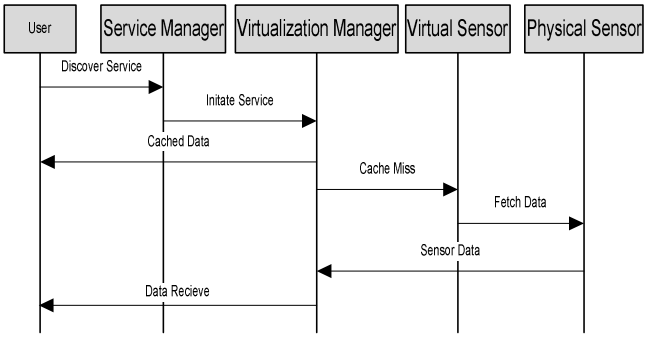

Fig. 3 Session establishment sequence chart

The middleware part that exists in on the sensor node provides sensor virtualization property using a hardware abstraction layer on top of the lower layers.

The proposed middleware is elaborated in fig .2, it can be seen between the application layer and the lower layers with multiple applications running on top and the lower layers with multiple low power communication protocols. Middleware ensures QoS for the health care data and utilizes all of the network resources for safe and real time data transmission. In case of an emergency it sets the applications having less priority to wait, like light sensing. Performing all these tasks the energy manager is always active in providing parameters to the other modules of the middleware enabling them to take energy efficient decisions. The sink node's role can be played by any sensor node at a time in the network. Albeit, this technique improves reliability, scalability and QoS but there must be further refinements to keep most of the nodes perform only sensing tasks rather than management. In order to reduce overall energy cost.

C. Session Establishment

The sequence of the session establishment in the proposed design is shown in fig.3. Session initiates with some user application requesting for the sensor data. The service execution is based on the request response mechanism. The request of the user application is tickled by the middleware. Service negotiation is the first part, if the requested service is available and can meet the demands of the user the request is forwarded to the virtualization manager at the node, if queried data is found in the cache of the sink node and additionally if the application running is not critical the cached data is returned immediately. However, if data requested is to be fetched from the sensor node virtualization manager takes the readings of the energy on the service providing node and then decides which virtual sensor is to be used or which logical group is to be formed. This way we can increase the lifetime of the sensor network. Virtualization manager goes through the whole process of consultation and the request is forwarded to virtual sensor or a group of virtual sensors. Furthermore, the request of the user is fulfilled by one of the virtual sensors, fetching data from the physical sensor node, and passing them to the requested node or sink that started the negotiation with the user.

V. CONCLUSION

The proposed node middleware framework for SHAAL is based upon the virtualization of sensor network that enables several independent applications to run on dissimilar sensor networks and nodes. The proposed node middleware provides dynamic allocation of resources in an energy efficient and secure manner, with increased energy awareness, diversity and manageability. The properties in turn improve the overall energy efficiency of the sensor networks. Our future research will be based on the evaluation and proof of the proposed middleware by the development of the test bed and to make framework more energy aware.

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