A Service Oriented Middleware for Smart Home and Ambient Assisted Living

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***Abstract*—Due to the complexity issue of developing heterogeneous Wireless Sensor Network application such as limited reusability, non-scalability, tight coupling between platform and application, a new middleware needs to be introduced to solve these problems. A distributed system framework such as Service Oriented Architecture (SOA) can definitely resolve these issues. SOA framework is able to hide the complexity lower layer to the application programmer and also create modular programming that can support different platforms. This paper aims to provide the service oriented middleware that supports heterogeneous services in Smart Home and Ambient Assisted Living (SHAAL) application.**

Keywords—wireless sensor network,smart home, service oriented architecture

I. INTRODUCTION

Throughout this decade, the Wireless Sensor Network (WSN) technology has achieved successful results, such as node development, application implementation, embedded operating system development and network protocol. These technologies enable the development of low power, low-cost and multi-operation sensor nodes that are in smaller size. It also increases the robustness, fault tolerance, efficiency and flexibility of developed embedded operating system and network protocol. WSN is composed of a large number of sensor nodes and multi-hop networking capability that are densely deployed for a wide variety of applications such as smart buildings, interactive user interfaces, environment control and highly suitable for monitoring in military and biomedical applications[1]. Figure 1 shows typical wireless sensor node architecture.

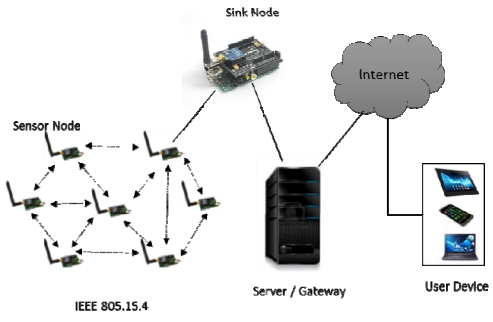

Fig.1 Wireless Sensor Network Architecture

WSN for SHAAL is an emerging potential technology that can offer services to enhance quality of living at home and at the same time can improve health and provide assisted independent living to individuals, patients, elderly and disabled people at home and nursing home [2-7]. The SHAAL systems composed of several sets of intelligence medical sensors, automated devices and heterogeneous wireless sensor nodes. All these sensors and automated devices are managed using intelligent control algorithm and work together in order to enhance the quality of life.

The most current problem in heterogeneous wireless sensor network is interoperability. Some of the current wireless sensor nodes are restricted to specific wireless technology and sensing capability. This makes the wireless sensor node with different technologies incompatible [8, 9]. For example, a motion sensor with Bluetooth technology cannot trigger the camera with Wi-Fi technology to capture a picture of intruder. Gateway service can be a solution to control and connect different wireless technology of sensor node but it poses difficulty of usage and maintenance.

In order to deal with the complexity and heterogeneous services, it is necessary to develop innovative solution that is capable of providing interoperability. The design and implementation of SHAAL application using traditional method is very difficult and requires a lot of development time. This is because it needs application developer to learn and familiar with many things such as programming language, programming technique, and operating system. The programmer must also understand the low-level programming, programming in a single node and familiar with hardware and network interfacing [10-12].

The complexities of the development of SHAAL application can be made easier by providing the high-level abstraction in order to hide the low-level functionalities from application developer. The above issues and challenges in the design of SHAAL demand an open architecture approach in the development of middleware that supports modularity, autonomous, interoperability, scalability, low power consumption and resource utilization.

This paper is organized as follows. In section 2, we discuss the existing works that have been carried out on SOA

middleware for WSN. Subsequently in section 3, the proposed architecture for SOA middleware for SHAAL application is introduced. Finally the last section presents the conclusion of this paper.

II. Related Work

Recently, several efforts have been carried out on the implementation of SOA into wireless sensor network middleware for various applications.

A Web Service Middleware for Ambient Intelligence (aWESoME)[13] is a middleware developed to address the issues of universal, homogenous access to the system function and fulfill functional and non-functional that requirements from the system architecture. It is based on ambient intelligence environment and consumed low power without compromise, with reliability and fast response time. To develop the complete architecture paradigm with provisioning capabilities, service broker has been used.

USEME[14] middleware allows the combination between microprogramming and node centric programming to develop real-time and efficient application for wireless sensor and actuator network. It provides the real-time specification between services uses group network structure and supports dependent-free platform. The USEME middleware allows the programmer to create application without knowing the low level detail and repetitive task in heterogeneous wireless sensor network. It is suitable for various wireless sensor network application developments.

HERA[15] is an upgraded version of services layer over light physical device (SYLPH), which is based on a distributed platform and implemented using an SOA approach into heterogeneous wireless sensor network. The HERA architecture is able to operate into various sensor nodes platform with independent wireless technology, architecture and programming language. It also uses reactive agents with case-based planning features to recover from error by considering the previous history. Generally, HERA can work together with wireless devices from different technologies in a distributed way.

A micro Subscription Management System (μSMS)[16] middleware has been proposed for smart infrastructure over wireless sensor network by using service oriented architecture as a software architecture. The approach of this middleware is to specify and develop the notion of virtual sensor services created for Smart Environment via sensor network from tiny in-network services by using agent based technology. The developed middleware provided medical status monitoring, perimeter surveillance and location tracking. Generally the main purpose of this middleware focuses on translating the wireless sensor network architecture into internet based architecture for world smart digital ecosystem.

Knowledge-Aware and Service-Oriented (KASO)[17] middleware tries to integrate the wireless sensor and actuator network with service cloud. The main key element of KASO is to offer advance and enrich pervasive services to everyone connected to internet. It will implement mechanism and protocol which allows managing the knowledge generated in pervasive embedded networks in order to disclose it to internet user in a readable way. The energy consumption, memory and bandwidth are considered in developing of KASO middleware.

OASIS [18] middleware provides abstraction for object centric, service-oriented sensor network application, and ambient-aware. It also provides location tracking to track the heat source. The programming framework for OASIS enables the program developer not having to deal with low-level system and network issues and also provides well-defined model. It also decomposes specified application behavior and produces the suitable node-level code for placement into the sensor network.

The development of middleware based on function block programming abstraction in [19] provides reprogramming of sensor node with new applications by injecting the base station with a mobile agent. It also facilitates flexibility and adaptability features by making their operation more complete and efficient even in dynamic environment and at the same time keeping the complexity and overhead programming low. Wiring concept has been used to link between function blocks in order to develop the application. This method will hide the underlying hardware and software complexity from the application programmer.

TinySOA[20] is a service oriented architecture middleware that lets programmers access WSN from their application based on a simple service-oriented API over by their own language programming. The approach does not take into the account non-functional capability. It consists of four components such as gateway, node, server and registry. The scope of TinySOA is to cover monitoring and visualization application. The general target of TinySOA is to facilitate the technique developer control and access of wireless sensor network and incorporate them into application implementation.

WSN-SOA[12] middleware has been designed to support network dynamicity, service discovery, automatic configuration mechanism and interoperability. The main idea of this middleware is to enhance SOA capabilities into limited capabilities device such as WSN sensor node platform and provide self-configuration mechanism for both network and services. This node middleware will be divided into three classes which consist of full capacity node (no resource limitation), limited capacity node (such as, battery, processing power and communication capability) and low capacity node (extremely limited resource). Generally, this proposed middleware supports multi-level service oriented architecture for sensor network and ties gap between devices platform having different capabilities.

In summary, several of existing service oriented middleware's has been introduced. Only a few of the services oriented middleware's support recovery services. Recovery services are very important to develop autonomous and self-configure services in SHAAL application. None of the stated service oriented middleware's mentioned above includes security service. The security service is very important to protect the privacy of the service and data. The proposed service oriented middleware in this project provide the reprogramming, recovery and security services.

III. The Proposed Middleware

The proposed service oriented middleware for SHAAL application must be able to provide mechanism to support heterogeneous services with various capabilities such as recovery, resource utilization, reprogramming and security. It also provides the abstraction layer to hide the low level function. Figure 2 shows the proposed service oriented architecture framework for SHAAL application. The application contains more than one service at a time and dependent on the operation of application. Different applications can use the same service at the same time thus, provides reusability. Service oriented middleware will provide application programmer interface (API) to application developer to access and manipulate the service offered by the sensor node.

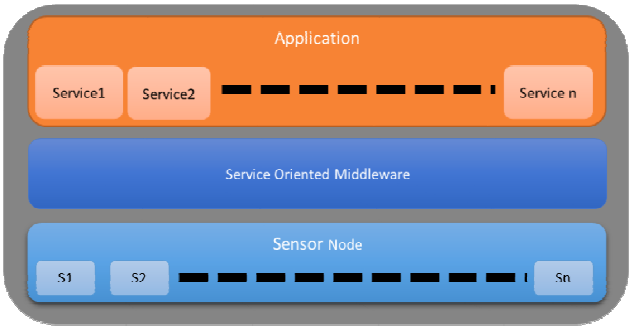

Fig. 2 Service Oriented Architecture Framework for SHAAL

Figure 3 shows the service oriented middleware architecture for SHAAL application. It consists of seven management modules where four are in service management and three are in the network management. They are security management, context management, service management, QoS management, communication management, resource management and power management.

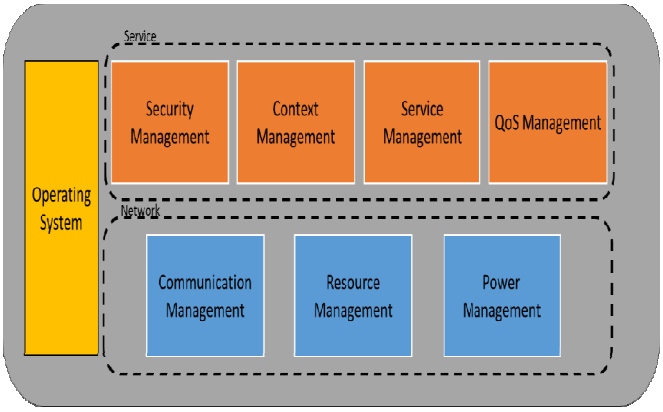

Fig. 3 Service Oriented Middleware Architecture

A. Security Management

The security management module is to ensure the authenticity, authority, integrity and confidentiality. The sensor node needs to register itself into the network before it can participate in the network and only selected sensor node can request and publish the service. To prevent the third party to reveal the actual content of the communication, all the actual data transmitted by sensor node will be encrypted.

B. Context Management

Context management module consists of two main modules which are adaptive module and configuration module. Adaptive module is responsible to collect the information from environment. The configuration module will configure the service based on the data gathered by adaptive module. For example, when the sensor node is in low power condition, it will invoke the adaptive management through power management to inform the current situation. For the next transmission, configuration module will reduce the node power transmission.

C. Service Management

Service management will manage the service coordinator, service recovery and service publish/discovery. Service coordinator will handle the service request, service register and service response from application. To achieve the continuity of system operation, the recovery component is needed to handle service failure. When the service failure occurs during the run time, recovery component will try to find the available solution to solve the problem. If recovery component fails to solve the problem, it will inform the application layer about the failure. For example, if a node unable to send the data to destination, it will inform recovery component to solve the problem. Recovery component will find available sensor node that can use some of their energy in searching a new path and tries to resend the undelivered data to destination node.

A publish/ discovery component is responsible to keep and maintain record of the service published by the node in the network. When the nodes require the service, the broadcast request will be transmitted to the network in order to search which node provides that services. In the network, when a node receives the request transmission, it will check whether it can provide the services or not. If yes, the corresponding node will respond to the request. If not, the node will not respond the request.

D. QoS Management

The purpose of QoS management is to manage and handle the different requirement of QoS for different services. Every service in the system will set the priority of execution such as low priority, medium priority and high priority. The service with high priority will be executed first, followed by medium priority and low priority services. For example, fire alarm services will be set as high priority and read temperature service as low priority. When fire alarm services and read temperature service are triggered at the same time, the QoS management will give priority to fire alarm services to execute first and then followed by read temperature service if there is no more high priority services in the buffer. The service priority will be configured by the application developer.

E. Communication Management

Communication management component are responsible for managing inter-node communication in the network. The whole components in the middleware will provide the standard

interface via radio interface in order to execute the events of receiving and transmission tasks.

F. Resource Management

Resource management is responsible for managing resources in the network such as network bandwidth, memory capacity, processing power and battery resource. Resource management will provide efficient utilization of the system resources in the network.

G. Power Management

Implementation of power management component into middleware can optimize the power consumption of node during the run time. Power management will manage the node power transmission, sleep and wakeup of the wireless module process.

IV. Conclusion

This paper introduces the concept of service oriented middleware that supports heterogeneous services in the SHAAL application. The proposed service oriented middleware should be able to support interoperability, heterogeneous services, low power consumption, quality of service and reliability. In the implementation work, the details of each component will be designed, developed and tested experimentally. It is expected that the project will produce a middleware that provides smooth services to the various applications in SHAAL. The middleware platform that allows reprogrammable WSN can be an asset that leads to development of more potential applications such as smart cities.

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