Middleware:Middleware Approaches and Evaluation Framework for Wireless Sensor Networks

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***Abstract*—Now a days we have deployed so many WSNs to observe Environment and for process control in industry. Different Sensor use different hardware and communication protocol. We need a coherent infrastructure that bridge gap between WSN and application. In This Paper presents different middleware approaches and its evaluation framework designed for Wireless Sensor network. There is lots of existing middleware solutions available for WSN. We introduce different middleware approaches and categorize these middleware solutions. Based on four evaluation parameter these middleware solutions are compared and analyzed in this paper. Evaluation results are shown in this paper represent some ideas to build middleware solution based on application requirements and also open new issues for further research in wireless sensor network.**

Keywords—Middleware; WSN; Wireless Sensor Network; Evaluation Framework

I. INTRODUCTION

A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. Now a day's sensor becoming cheap, tiny and smart. We have been deployed so many sensor networks to observe Earth's environment phenomena, industry process and more will follow in future. While a sensor is the most basic unit, a sensor system is an aggregation of sensors, attached to a single platform [1]. Due to huge amount of sensor industrialists and differing supplementary protocols, integrating diverse sensors into application is not straightforward .To integrate sensor data into application we need a infrastructure or architecture that bridge gap between Sensor and Application layer.

Middleware layer reflects such kind of concept or infrastructure that can abstract physical layer detail from the application built on top of it. It also can act as a layer between sensor nodes and user side server. A middleware layer is a innovative approach to fully meeting the design and implementation challenges of wireless sensor network and application development. We can visualize WSN middleware as a software infrastructure that glues together the network hardware, WSN operating systems, network stacks, and WSN applications. A complete middleware solution should solve problem related WSN and make WSN deployment, maintained easy. It should contain a runtime environment that supports and coordinates multiple applications, and standardized system services such as data aggregation, control and management policies adapting to target applications, and mechanisms to achieve adaptive and efficient system resources use to prolong the sensor network's life.[2]

There are lots of existing middleware solutions available with different features and mechanisms. We will discuss middleware advantages and weaknesses. After that we will introduce existing middleware technology, and classified them into categories, make a comparison and analyze.

II. AN OVERVIEW OF EXISTING MIDDLEWARE ON WSN

A. Middleware Approaches

There are many research groups present a lot of middleware approaches both on theoretical ideas and practical projects. They mainly can be classified into 7 classes according to middleware architectures and approach mechanisms [3], we list them below.

Distributed database

This middleware approaches treats the whole sensor network as a distributed database. In order to get observations users just have to query the database of WSN. it has a very user friendly and easy to use interface. It is good for an ease of operation, but doesn't support real time applications, so sometimes it only provides estimated results

Mobile agents

The main goal of mobile agent middleware is that it treats applications as modules for injection and distribution through the WSN using mobile modules. It allow user to develop application in small modules and inject into network so, it can consume less time and power than big application. It is efficient and flexible approach to support for multi-purpose WSN and dynamic application update. The weakness of this model is that it doesn't provide hardware heterogeneity.

Virtual machine

This middleware approach is aim at to minimize overall power and resource consumption. The system contain virtual machines and interpreters. Let Developers to write applications into small modules, and injecting and distributing modules through WSN, and virtual machines interpret the modules to

implement application. This approach is good for to minimize power consumption but it doesn't support heterogeneous application and introduce high overhead.

Application Driven

This middleware allow user to fine tune network to fine tune network according user requirements for some specified purpose. Application driven middleware could adjusts network Qos parameters according to application requirements. It has a Architecture that supplies multiple network configurations by choosing suitable protocol in its network protocol stack. However it is tightly Coupled with application we can't use this middleware for general purpose.

Message-oriented

Message-oriented middleware implements communication between application and WSN using publish/subscribe mechanism implements the communications using publish/subscribe mechanism. In this case sensor act as producer and application act as a consumer. it reduced unnecessary communications when applications collecting data based on specified purpose and events. Strength of this middleware is that it provide asynchronous communication between Sender and receiver and it is loosely coupled that decouples sender and receiver.

B. Existing middleware technologies

Cougar

This project falls into Database category. This approach is very appropriate for large sensor networks and offers an easy-to-use interface based on database query system for different operations. However, it uses valuable resources to transfer large amounts of raw data from sensor nodes to the database server. The possible risk for communication failure in a extensive sensor network makes Cougar's power awareness limited [4].

Impala

This project falls into category of mobile agents. Impala is using modular programming approach. The whole architecture design is divided into two level layers: upper layer contains all the necessary protocols and application programs and the lower layer consist of middleware agents such as Application Updater, Application Adapter, and Event Filter. Impala support multiple different applications which located in upper layer by adapting, updating and event filtering data from lower layer. The Impala is original designed in Zebra Net Project, which is developed for wildlife tracking in large area with limited communications devices. It provide good performance for mobile sensors, lower time and lower minimize data volume for communication.[5].

Mate

This project falls into category of Virtual machine project. Mate aims to provide better communication and adaptation to the ever-changing nature of WSN. It supports frankness and scalability by active messages to update the network infrastructure and configuration by injecting new capsules. Mate is small and expressive and has concise programs that makes the network dynamic, flexible, and easily reconfigurable. Mate doesn't provide hardwere heterogeneity and introduce extra overhead because of interpretation model. [6]

Mires

This middleware approach falls into category of message oriented middleware .Mires is middleware solution that runs and implemented on TinyOS. This middleware based ob publish subscribe mechanism. It exchanges message between sink node and application using publish/subscribe mechanism. It contains public/ subscribe service, routing components and additional services. The key feauter is the public/ subscribe service. it act as middle layer to transfer publish/subscribe message, and further more to establish communications between sensors and user applications. Each node acts as a producer that produce data and application acts as consumer that consume data.[7]

III. EVALUATION AND ANALYZE

A. Abbreviations and Acronyms

We will evaluate the existing middleware solutions mentioned above base on following evaluation criteria: scalability, Real time service, heterogeneity, loose coupling.

- **Scalability:** "If an application grows, the network should be flexible enough to allow this growth anywhere and anytime without affecting network performance"[3].Middleware should be flexible enough to number of nodes that produce the data and number of application that injects application knowledge into network. Most of time WSN topology is dynamic so, middleware should support sensor nodes maintenance and reconfiguration.
- **Heterogeneity:** Middleware should provide mechanism that abstract various types of hardware and communication protocol. Middleware should be capable of support different type of sensor hardware and communication protocol. The middlewares which run on single operating system or virtual machine, we determined them as medium supporting. For the middlewares which only designed for certain hardware, we determined them as weak supporting. For example, Runes is determined as strong support on heterogeneity, virtual machine based middlewares and middlewares run on the top of TinyOS are determined as medium, and Impala is determined as weak.
- **Coupling**:Middleware which is designed for an specific purpose and provide support for set network parameter according to application requirements we determine them tightly coupled with an application and middleware which is designed for general purpose and not for specific purpose we determine them loosely coupled.
- **Real Time**: Most of sensor network application deals with real time phenomena. Middleware which provide consistent data to application in asynchronous manner as well as event happen we determine them to support real time data.

B. *Result of Evaluation*

In This Paper we evaluate following existing middleware based on four evaluation criteria: scalability, Real time service, heterogeneity, loose coupling and results are shown in below table

Middleware	Scalability	Coupling	Real Time service	Heterogeneity
Virtual Machine based Approach				
Mate, Univ. California Berkeley	Full	Tight	NO	Partial
Database based Approach				
Cougar, Cornell Univ.	Little or None	Tight	NO	Little or None
SINA, Univ. Delaware	Little or None	Tight	NO	Little or None
Modular Programming based Approach				
Imapala, Princeton Univ.	Full	Tight	YES	Little or None
Message Oriented Middleware				
Mires, Univ. Pemambuco	Full	Loose	YES	Partial

IV. CONCLUSION

In this paper we have discuss various middleware approaches and existing middleware solutions available in these approaches. We evaluate different middleware solutions based on WSN application requirements and present middleware solution suggestion for different type of application requirements. We hope those ideas and evaluation framework are very helpful for designing middleware solution and further research.

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