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By Qun Yu

Entitled Design and Implementation of Web-based Data and Network Management System for Heterogeneous Wireless Sensor Networks

For the degree of Master of Science

Is approved by the final examining committee:

Yao Liang
Chair

Xukai Zou

Yuni Xia

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DESIGN AND IMPLEMENTATION OF WEB-BASED DATA AND NETWORK MANAGEMENT SYSTEM FOR HETEROGENEOUS WIRELESS SENSOR NETWORKS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Qun Yu

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of

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ABBREVIATIONS

ABBREVIATIONS	DESCRIPTION
GW	Gateway
GWS	Gateway Set
H-WSNMS	Heterogeneous Wireless Sensor Networks Management System
MR	Metadata Repository
MSA	Management Service and Application
OTAP	Over-the-air Programming
SC	Service Component
SOA	Service Oriented Architecture
TC	Target Command
TCS	Target Command Set
UG	Unified Gateway
UGA	Unified Gateway Access
VC	Virtual Command
VCA	Virtual Command Attributes

VCAS	Virtual Command Attributes Set
VCC	Virtual Command Category
VCS	Virtual Command Set
VCSMM	Virtual Command Set Mapping Model
WSN	Wireless Sensor Network
WSNs	Wireless Sensor Networks
XML	Extensible Mark-up Language

ABSTRACT

Yu, Qun. M.S., Purdue University, August, 2010. Design and Implementation of Web-based Data and Network Management System for Heterogeneous Wireless Sensor Networks. Major Professor: Yao Liang.

Today, Wireless Sensor Networks (WSNs) are forming an exciting new area to have dramatic impacts on science and engineering innovations. New WSN-based technologies, such as body sensor networks in medical and health care and environmental monitoring sensor networks, are emerging. Sensor networks are quickly becoming a flexible, inexpensive, and reliable platform to provide solutions for a wide variety of applications in real-world settings. The increase in the proliferation of sensor networks has paralleled the use of more heterogeneous systems in deployment. In this thesis, our work attempts to develop a new network management and data collection framework for heterogeneous wireless sensor networks called as Heterogeneous Wireless Sensor Networks Management System (H-WSNMS), which enables to manage and operate various sensor network systems with unified control and management services and interface.

The H-WSNMS framework aims to provide a scheme to manage, query, and interact with sensor network systems. By introducing the concept of Virtual Command Set, a series of unified application interfaces and Metadata (XML files) across multiple WSNs are designed and implement the scalability and flexibility of the management functions for heterogeneous wireless sensor networks, which is demonstrated though through a series of web-based WSN management Applications such as Monitoring, Configuration, Reprogram, Data

Collection and so on. The tests and application trials confirm the feasibility of our approach but also still reveal a number of challenges to be taken into account when deploying wireless sensor and actuator networks at industrial sites, which will be considered by our future research work.

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CHAPTER 1. INTRODUCTION

1.1. Research Background

A wireless sensor network (WSN) [1] consists of spatially distributed autonomous sensors cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration pressure motion or pollutants. The development of wireless sensor networks (WSNs) was motivated by military applications such as battlefield surveillance. They are now used in many industrial and civilian application areas, including industrial process monitoring and control, machine health monitoring, environment and habitat monitoring, healthcare applications, home automation and traffic control and so on.

Wireless Sensor Networks have become an emerging new research area in the distributed computing environment. It plays an important role in the pervasive computing to support a wide range of applications of the daily life in future. So far, as heterogeneous WSNs are being widely deployed for various applications, we are faced with a new challenge of network management for heterogeneous WSNs. On one hand, current available WSN management tools are either application specific, or platform specific, thus suffering from the lack of reusability in heterogeneous WSNs management environment. On the other hand, to develop a new WSN management system for heterogeneous WSNs from scratch is time consuming and may not be feasible. Motivated by such a challenge, a major impediment in the integration process is represented by the variety of customized platforms and proprietary technologies. In this thesis, we propose a unique, open, scalable and flexible WSN Management Comprehensive Application Platform targeted for Heterogeneous WSNs Management System.

Our prototype system H-WSNMS provides a Web-based Data and Network Management Environment for Heterogeneous Wireless Sensor Networks.

This research topic is very important to allow large-scale heterogeneous WSNs to be effectively and easily managed and operated in the real-world tasks and applications.

1.2. Research Goal

In this thesis, our main goal is to put forward a Heterogeneous WSNs management system solution scheme and implement it based on a prototype environment. This system should have the following features as described:

- A unique, open, scalable and flexible WSN Management Comprehensive Application Platform Architecture
- A Service Oriented WSN management platform
- A scalable Unified Gateway across multiple WSNs

In the design of our H-WSNMS architecture, some key component designs are involved, such as Service Mapping design and Unified Gateway Access design. In this thesis, we adopted the application of the Extensible Mark-up Language (XML) which enables a new level of interoperability for heterogeneous IT systems.

Using a common reference model improves this process and leads to Virtual Command Set Mapping Model (VCSMM): Service Mapping. The results can be used immediately to configure mediation layers integrating services into an overall service oriented architecture. Besides, the Unified Gateway Access is designed for integrating various different wireless sensor platforms and accessing the third part gateway interfaces with other standards, which is flexible and extendable.

CHAPTER 2. RELATED WORK

2.1. Current Sensor Network Platforms

2.1.1. MoteWorks Platform

Crossbow [4] was one of the first suppliers of the Berkeley-style MICA motes [4] which employ the TinyOS operating system. Follow on products include the MICA2 [4] (868/916 MHz) and MICAz (2.4 GHz) motes as shown in Figure 2.1, and the Intel-designed IMOTE2. Crossbow also makes a software design platform for its hardware called MoteWorks.

The MICA2 Mote is a third generation mote module used for enabling low-power, wireless sensor networks. The MICA2 processor radio is fully supported by the MoteWorks Software Platform.

MICAz is a wireless sensor network mote developed by Crossbow Technology. The device is built upon the IEEE 802.15.4 standard. It is one of the most commonly used mote system in the world.

Figure 2.1 Sensor Platform: MICAz

2.1.2. Particle Platform

The Particle node [13], produced by Particle Computer, comprises a communication board with the PIC18f6720 microcontroller and TR1001 transceiver. Various types of sensors can be attached to the communication board. The wireless communication uses the AwareCon protocol [20], which is designed to handle high mobility and density of nodes. This makes the Particle platform as shown in Figure 2.2 well suited for equipping chemical containers handled by human operators and checking potential dangerous situations.

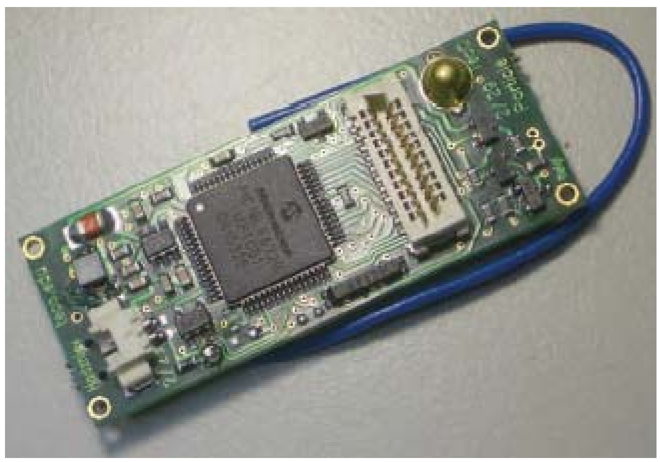


Figure 2.2 Sensor Platform: Particle

2.1.3. μNode Platform

The μNode platform [14] as shown in Figure 2.3, produced by Ambient Systems, represents a low-power, general purpose sensor node, built around the MSP430 microcontroller and a single- chip radio transceiver for the 433/868/915 MHz ISM band. After deployment, the μNodes self-organize into a multi-hop network, through which data can be routed back and forth to a designated sink node. This platform is ideal for building large-scale sensing infrastructures that can function unattended for long periods of time. Since many chemicals must be stored under specific ambient conditions, we use the μNode sensors for continuously monitoring environmental conditions.

Figure 2.3 Sensor Platform: μNode

2.2. Sensor Network Middleware Architectures

Some of the "hot" topics in WSN software research include such as Security, Mobility (when sensor nodes or base stations are moving) and Middleware (the design of middle-level primitives between the software and the hardware). This thesis focuses on the research on sensor network middleware architectures.

Today, due to the unique challenge of WSN [2], typically the platforms are specialized for specific purposes (e.g. data collection, target tracking), it is often the case that complex applications require the combination of multiple proprietary technologies and heterogeneous wireless sensor platforms. As a result, the management, monitoring and administration of a system with highly distributed logic are a very complex task. Without the right tools and architecture, it can increase the total cost of ownership to a point where the deployment of this technology becomes commercially uninteresting.

2.2.1. MoteView Framework

MoteView [5][9] presents a scalable software framework for managing, monitoring, and visualizing sensor network deployments developed by Crossbow. It provides tools to the users to visualize results from a sensor network. Readings arriving from the network are stored in a relational database. The sophisticated interface is used to check the motes readings on the fly, visualize the topology, produce graphs from selected motes, check their status and export the readings to a spreadsheet.

2.2.2. Atlantis Framework

The Atlantis Framework [15] is based on TinyML but addresses several of its shortcomings. The basic elements are the same, i.e., it can describe fields, platforms, and sensors. Additionally, the Atlantis Framework adds data handling abstractions, and a query field for more detailed queries. It makes further improvements by defining a field task object which can handle asynchronous data retrieval. For this purpose, it adds an additional data broker which handles the tasks, and specific broker behaviors to describe how to handle the task itself. As a nice roundup, the Atlantis Framework adds data filters and event subscription possibilities. On the downside, there is not a standard way to manage the sensor systems since a registry does not exist.

2.2.3. Decentralized Enterprise Systems Framework

The overall architecture of the Decentralized Enterprise Systems framework [11][12] used a service-oriented architecture (SOA) as a platform construct.

SOA architecture is very helpful in solving the issues in the design of the management system. The integration efforts are minimized by hiding much of the implementation details and exposing only the functionality of the WSN in use. The management also is simplified because the logic is encapsulated in services with a manageable granularity. The services can be deployed, removed, or upgraded from a central location to adapt the system to the business requirements. In this thesis, we focus on the integration of various WSN platforms for management and operation purpose. SOA architecture based on Web services technology recently have become popular for building complex yet flexible enterprise Web-based Management Systems.

CHAPTER 3. H-WSNMS ARCHITECTURE

3.1. H-WSNMS System Framework Overview

H-WSNMS is structured on various Wireless Sensor Networks, hiding the heterogeneity of WSNs, and providing a basic WSN Service Management platform to web_based WSNs Service and Application Users. This kind of platform should satisfy three aspects:

- Open multi-function access oriented services system: the platform adopts an open system architecture and technology scheme. In this platform, the division of function entities, distribution of service functions and corresponded interface should abide by open standard;
- Unify service support environment;
- Improve service search and generic fame component according to the requirement: Quick deploy new services.

Based on the discussion above, H-WSNMS presents a three-layer architecture that accommodates different sensor platforms and exposes their functionality in a uniform way to the business application.

- Management Service and Application layer
- Unified Gateway (or Platform Abstraction) layer
- Mote (or Device) layer

These three layers are illustrated in Figure 3.1 and discussed in detail throughout the following subsections.

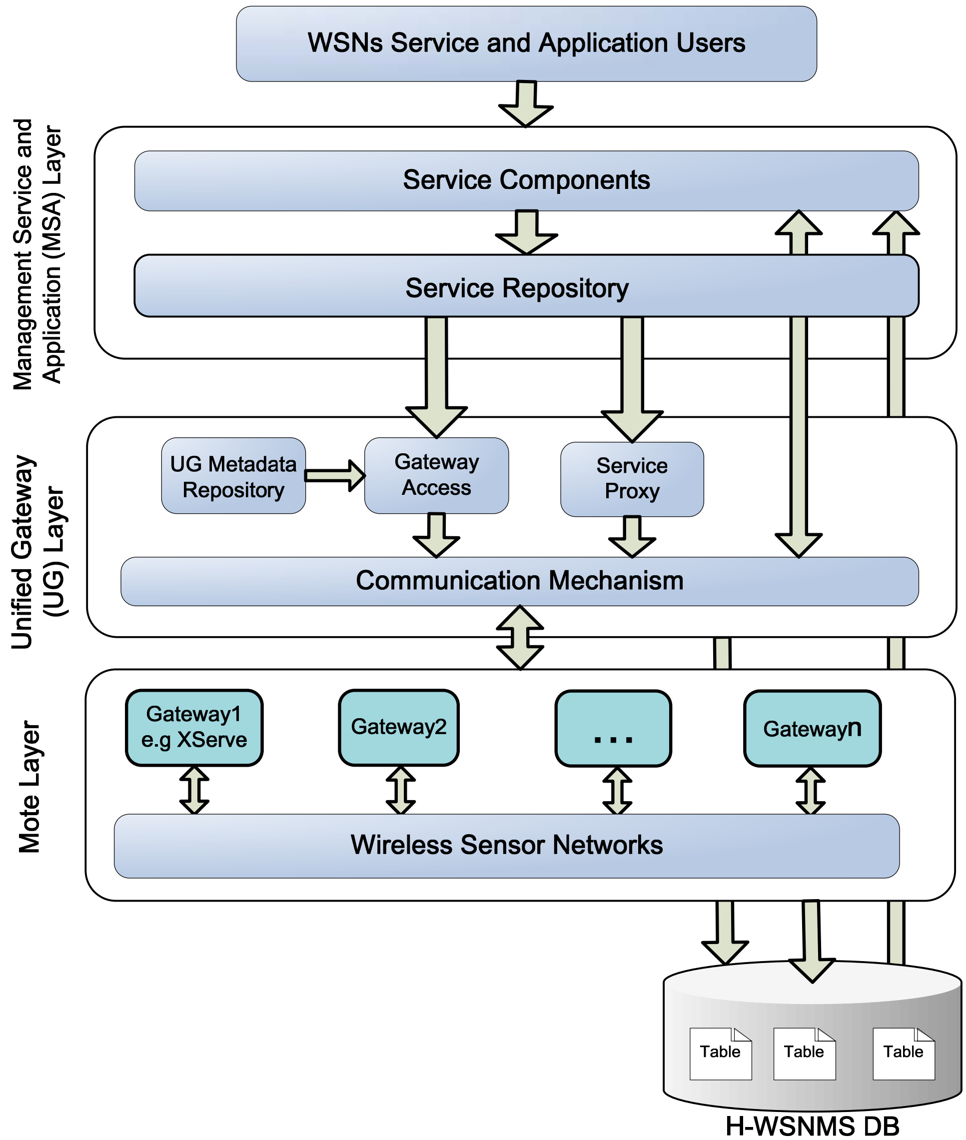


Figure 3.1 H-WSNMS System Architecture

From Figure 3.1, we can see, H-WSNMS System Architecture contains three layers:

- Management Service and Application (**MSA**) Layer
  This layer is the composition of different WSN management components, each of which is tailored for application requirements and independently

performs some specific functions that are defined by Service and Application Client and are described in Service Repository.

- Unified Gateway (**UG**) Layer

  This layer is the core of our proposed H-WSNMS architecture that is responsible for interpreting each Virtual Command from Virtual Command Set (VCS) into a Target Command(s) for WSN gateway(s). In this layer, the Service Proxy component provides a mapping function between Service Components in MSA layer and WSN gateway Command Service(s), displaying the multiple management functions accessing multiple WSN applications. Besides, the two control components, Gateway Access component and Communication Mechanism component, build the communication bridge between MSA layer and Mote layer, responsible for transmitting the Target Command(s) to WSN gateways.

- **Mote** Layer

  This layer consists of, in general, multiple heterogeneous WSN gateways associated with their preliminary management Command Services.

During the above discussion H-WSNMS architecture, an important concept should be introduced here: Virtual Commands Set (VCS). By VCS, each management service component is deemed to be realized by a Virtual Command or a sequence of Virtual Commands from the VCS, and each individual Virtual Command could be either partially or completely mapped to a combination of some existing Command Services under the given WSN gateway (with its preliminary management Command Services), as shown by Figure 3.2.

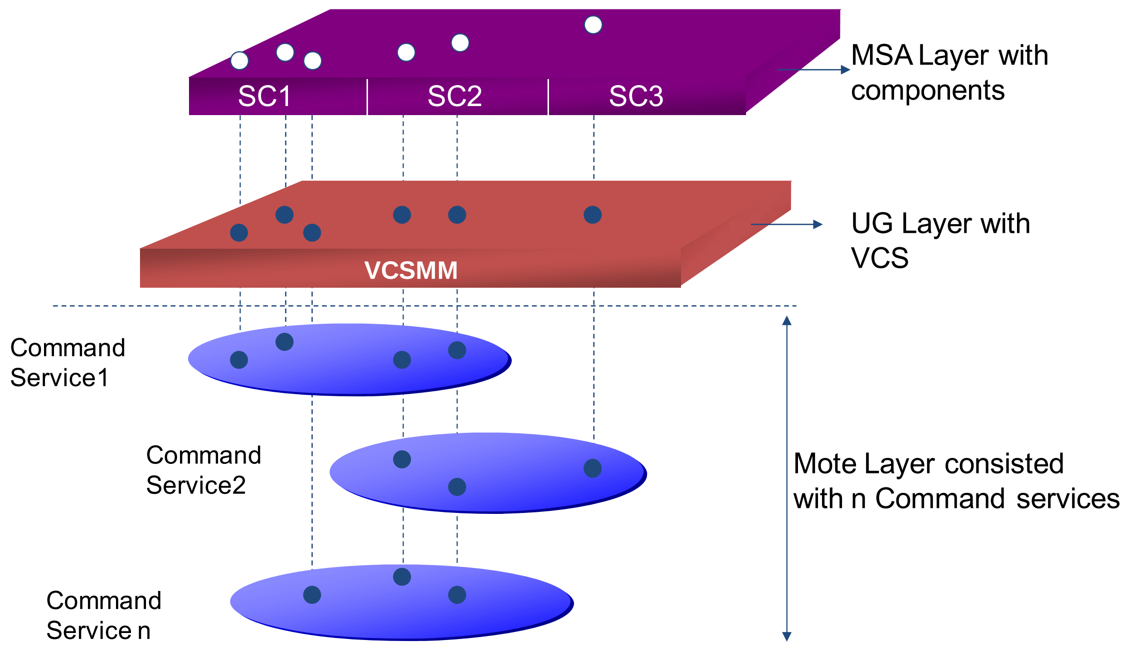


Figure 3.2 H-WSNMS with Virtual Command Set

In Figure 3.2, each plane presents a concrete WSN gateway Command Service, to which H-WSNMS maps some Virtual Commands. To realize the mapping from a subset of Virtual Command Set to a concrete WSN gateway Command Service, H-WSNMS adopts three-layer architecture. The top layer is the composition of different WSN management components. The bottom layer consists of multiple heterogeneous WSN gateways associated with their preliminary management Command Services. The middle layer is the core of our proposed H-WSNMS architecture that is responsible for interpreting and mapping each Virtual Command from VCS into a concrete WSN gateway Command Service(s), through this layer and the VCS, H-WSNMS can make management components more reusable across heterogeneous WSN platforms and also easier to develop, because developers can create management components based on predefined VCS and be freed from handling the details early on with the variety of WSN platforms, in the section 5.4 of Chapter 5, VCS reuse and extension are studied and implemented.

The advantage of VCS is that when a minor change on the commands service happens, just update some parameters configuration or add new parameters to complete new configuration in the interpreter. For understand this better, the content and format of VCS is defined in the Table 3.1. For this Wrapping and Interpreting procedure of VCS, we call it Virtual Command Set Mapping Model (VCSMM), which is discussed as one of key technologies in Chapter 4. The core UG layer in our proposed H-WSNMS architecture, working as an extensible and scalable interface between management components and concrete WSN gateway(s), provides an Access Adaption to specific WSN gateways, which also is discussed as another key technology in Chapter 4.

Besides, to illustrate implementation of the H-WSNMS architecture more detail, in the Chapter 5, we will present an instantiation based on specific WSN platform: Crossbow's MoteWorks [6].

In the following sections, the three-Layer structure is analyzed layer by layer.

3.2. Management Service and Application Layer

Management Service and Application (MSA) layer not only is able to provide management functionality, but also benefit from the uniform interfaces offered by the UG layer. In the Figure 3.3 gives us the detail about the MSA layer.

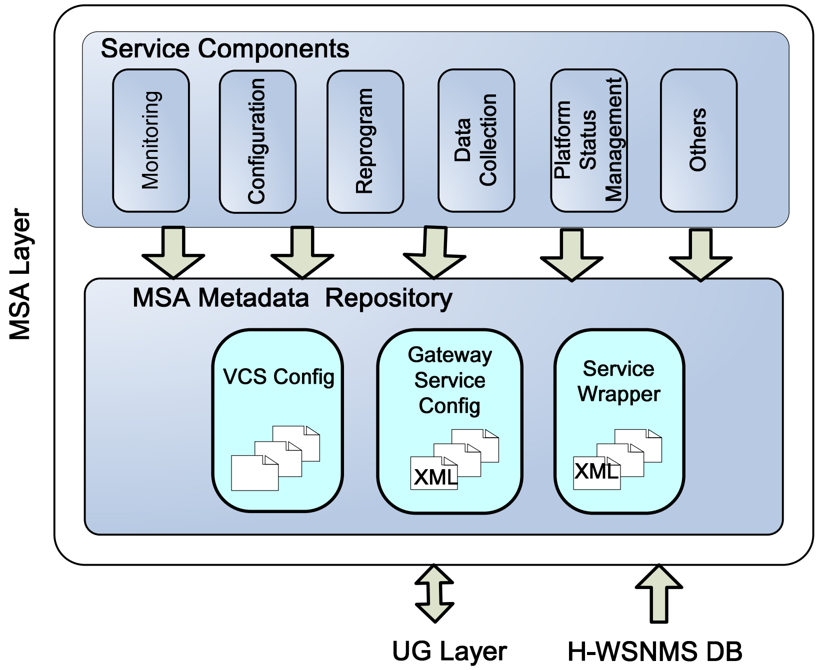


Figure 3.3 Management Service and Application Layer

There are two main parts in this layer:

- Service Components
- MSA Metadata Repository

  It contains a series of metadata documents in following components:

  - VCS Configuration
  - Gateway Service Configuration
  - Service Wrapper

3.2.1. Service Components

The MSA layer presents lots of various WSN management service components, the arguments of which, i.e. User request, which is called as Virtual Command in this system, are wrapped into Metadata XML file format stored in Service Repository.

The main service components involve Monitoring component, Configuration component, Reprogram component, Data Collection components and so on. The detail design and implementation will be introduced in Chapter 5.

3.2.2. MSA Metadata Repository

MSA Metadata Repository (MSA MR) component is a DB of available services configuration such as the VCS configuration, the target gateway service configuration, and XML documents containing the service description and so on. It is composed of the following parts:

- VCS Configuration

  A available file to define Virtual Command Category (VCC), which has two aims: one is to more conveniently describe service components from MSA layer; the other one is to help to automatically create socket communication port for management services with same type, i.e. the same type management services with the same WSN platform and same WSN gateway will share a same socket communication port. The code of port is composed of the code of VCC, the code of WSN platform and the code of WSN gateway. The latter two codes are described and defined in the Metadata Repository in UG layer. The Table 3.1 shows us the definition of VCC and Specification of VCS. The detail code of VCC, refer the Appendix A, which includes more details.

Table 3.1 Virtual Command Category and Specification of VCS

VCS	VC	Command	Function
Data Collection VCS H_DataColl	H_DataColl		Data collection
Monitoring VCS H_Monitoring	H_Monitoring		Monitoring sensor data
Configuration VCS H_Config	H_Config_Reconfig_SpRate	SET_RATE	Set new Sampling Rate
	H_Config_Reconfig_NID	SET_NODEID	Assign Node ID
	H_Config_Reconfig_GID	SET_GROUP	Assign a Node to new group
	H_Config_Reconfig_CRate		Set collection rate
	H_Config_Reconfig_ECollect		Immediately perform a data collection from WSN and store it to DB
	……	……	……
	H_Config_PM_RESET	RESET	
	H_Config_PM_SLEEP	SLEEP	
	H_Config_PM_WAKEUP	WAKEUP	
	……	……	……
Reprogram Set H_Repro	H_Repro_Boot		
	H_Repro_Query		
	H_Repro_Load		
	……		
Others	……	……	……

- Gateway Service Configuration

  A series of available files with format ".xml" or ".txt" configuring various WSN gateway status information, spatial information, the available gateway communication port information, and gateway middleware parameters information and so on. The detail design of XML template is shown as Table 4.3, Table 4.4 in Chapter 4.

- Service Wrapper

  It is a **XML Wrapper** responsible for describing service components in MSA layer, i.e. wrapping VC(s) corresponding to these service components with Metadata XML file format. The detail design of XML template is shown as Table 4.2 in Chapter 4. These XML files in Service Wrapper usually are sent to Service Proxy in UG layer to be mapped and interpreted into a target command string authorized by specific WSN gateways in the Mote layer.

3.3. Unified Gateway Layer

Owing to the difference of WSN gateways and diversity of command parameters indentified by motes in different WSNs, during the design of Unified Gateway (UG) layer, the system developers should statistics enough integrated information from Mote Layer, the purpose of which are to transfer various valid command strings to motes smoothly, to achieve gateways configuration correctly, and to guarantee gateway communication mechanism work successfully and so on. The design and implement of UG layer is not only a challenge but also an opportunity. The Figure 3.4 shows us the detail about the UG Layer.

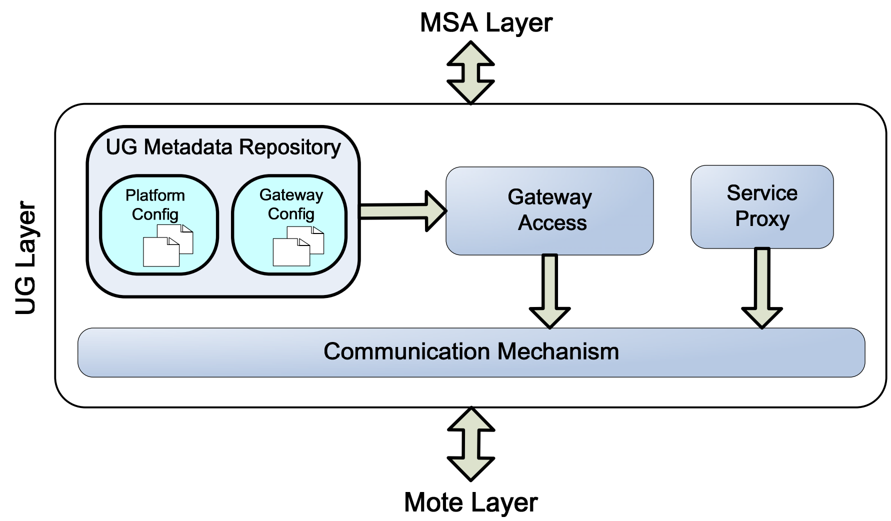


Figure 3.4 Unified Gateway Layer

UG layer is designed to harmonize different sensor platforms, i.e. heterogeneous sensor platforms.

- Responsibilities:
    - Handle the proprietary WSN mechanisms
    - Expose the service-oriented functionality through a standard interface
- Uniform Interface:
    - Facilitates the integration of the new platforms via a simple standardized mechanism

There are three main components in this layer:

- UG Metadata Repository

  It contains two type metadata documents as following:
    - Platform Configuration
    - Gateway Configuration
- Service Proxy

  A series of XML files in Service Wrapper are sent to Service Proxy in UG layer to be mapped and interpreted into a target command string authorized by specific WSN gateways in the Mote layer.

- Gateway Access

  It builds up the gateway middleware connection mechanism between UG layer and Mote layer.
- Communication Mechanism

  Socket Client- Server model is adapted in this system, which becomes the communication channel between MSA layer and Mote layer.

3.3.1. UG Metadata Repository

UG Metadata Repository (UG MR) is a series of available files to describe the information about WSN platforms and their gateways. It has two functions: one is to complete the respective configuration of WSN platforms, the corresponding specific gateways and gateway middleware application interface, and the other is to help to connect with mote layers through Gateway Access component and Communication Mechanism component. As mentioned in section 3.2.1, automatically created socket communication port for management services with same type needs the information about the code of VCC, the code of WSN platform and the code of WSN gateway. The latter two codes are described and defined in the Metadata Repository in UG layer. The detail code rules refer the Appendix A, which includes more details.

- Platform Configuration

  The target platform information is defined such as Platform Name and Platform ID and the corresponding Gateway Code in these metadata files
- Gateway Configuration

  The corresponding Gateway Name, Gateway ID and Gateway middleware application interface will be described in these metadata files

3.3.2. Service Proxy

It is a **XML Parser** responsible for systematic parsing and interpreting of the Virtual Command(s) with XML format wrapped by Service Wrapper to the target command strings indentified by the specific WSN gateways in Mote layer.

This Mapping processing is completed by Service Wrapper, presenting VCS with XML format and Service Proxy, containing a group of Service Proxies, which is command interpreter for a subset of VCS. That is to say, in H-WSNMS system, the combination of Service Wrapper and Service Proxy is a key Mapping Technology of H-WSNMS system implementation: Mapping Technology, which will be discussed in section 4.2.

3.3.3. Gateway Access

Through a series of available files configuring various WSN platforms, their different gateways information and relative gateway middleware information and so on, Gateway Access component builds up a connection mechanism with the specific gateway middlewares. The combination of MR component and Gate Access component is another key technology of H-WSNMS system implementation: Unified Gateway Access Technology, which will be discussed in section 4.3.

It is responsible for connecting the available application interfaces from the various different WSN gateway middlewares, take an instance of specific gateway middleware XServe in Crossbow WSN platform MoteWorks, which provides several different application interfaces such as XServe, XServterm and XOtap and so on. Through these application interfaces, the mapped target command(s) from Service Proxy is (are) sent to the specific WSN gateway(s) to complete various WSN management or data collection functions. About Gateway Middleware XServe will be introduced as an instantiation of system implementation in Chapter 5.

3.3.4. Communication Mechanism

Communication Mechanism component adopts Socket Client- Server Model to realize the communication between MSA layer and Mote layer. After Service proxy interprets and parses Virtual Command(s) described by XML file, the output mapped target command string(s) will be sent to the WSN gateway through this Communication Mechanism component. The socket port is automatically created based on the code of VCC, the code of platform and the code of WSN gateway, in another words, these code information should be defined at the beginning by system developers as illuminated in the Table.3.1, Appendix A and Appendix B, the detail definition of Port No. (i.e. Socket Port) will be introduced in section 4.4.3.

3.4. Mote Layer

The Mote Layer, the system hardware layer, building the real word wireless sensor network or wireless sensor networks. Each wireless sensor network has its own base gateway, communicating with its specific base station. The UG Layer provides a Unified Interface and Communication Mechanism to access every wireless sensor network to compete wireless sensor data and network management.

3.5. H-WSNMS DB

H-WSNMS Database is a DB of available services, storing the updated information from Mote Configuration and the updated Platform status, and the motes data that can be retrieved from Wireless Sensor Networks through Date Collection function. The PostgreSQL database technology helps us to complete this part.

3.6. System General Function Logical Flow

After introduction of H-WSNMS Three-layer architecture and the components in each layer, we can overview the whole system design like Figure E.1 in Appendix E shows us.

Now we give the general control and status information flow for generic functions in H-WSNMS system as illustrated in Figure 3.5. At the beginning, Users send a request to Function components in the MSA Layer, then the requesting information, i.e. Virtual Command(s), is sent to the UG layer and is wrapped into XML file(s) as attribute values in the Service Wrapper, which is(are) parsed and interpreted by the Service Proxy into the target command string(s) identified by WSN gateway(s) in Mode Layer, after its(their) own interpreter(s), then the WSN gateway(s) send the authorized command streams with binary format to the Base Station(s), which broadcast them into motes in WSNs. So far, the Requesting processing as the solid line shown has been completed, after mote(s) receives and executes the commands, they will response the corresponding information back to the WSN Base Station, and then the Base station transfers this information to WSN gateways to translate and send the data and WSN information back to Users through Unified Interface. During the Response processing as the dash line shown, the retrieved data from WSNs motes and the updated information about platform status are stored into H-WSNMS DB. We will overview several functions in detail such as Monitoring, Reconfiguration and Reprogram one by one in the later Chapter 5 to show the different logic flows of various management functions.

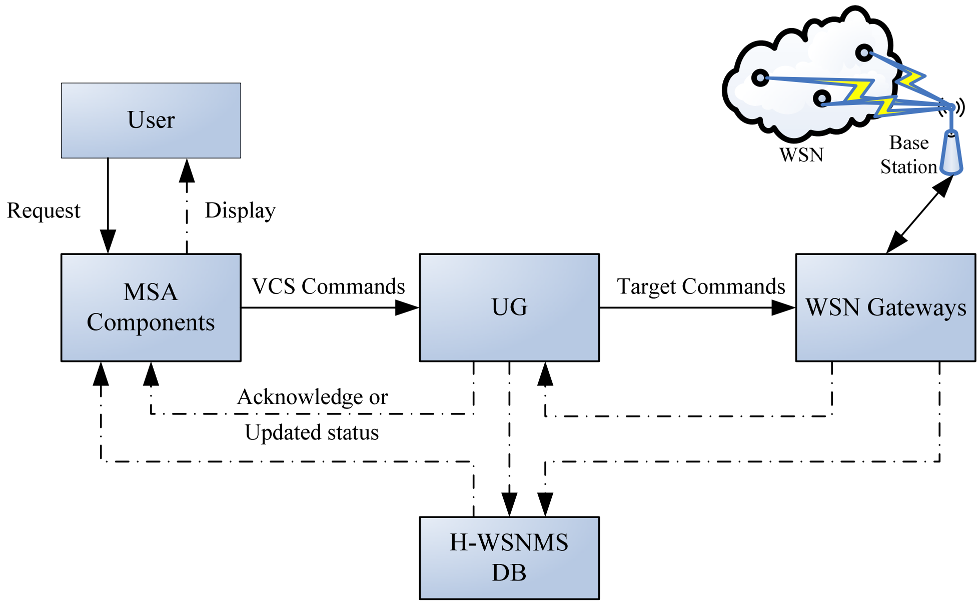


Figure 3.5 General control and status information flow for Generic Functions

CHAPTER 4. H-WSNMS KEY TECHNOLOGIES AND IMPLEMENTATION

4.1. System Logical Architecture and Key Technologies Overview

This Chapter will focus on discussion of the key technologies and system implementation. Figure 4.1 shows us the Logic Architecture of H-WSNMS, which involves two key parts during the design and implement of H-WSNMS: Mapping Fame and Access Adaption.

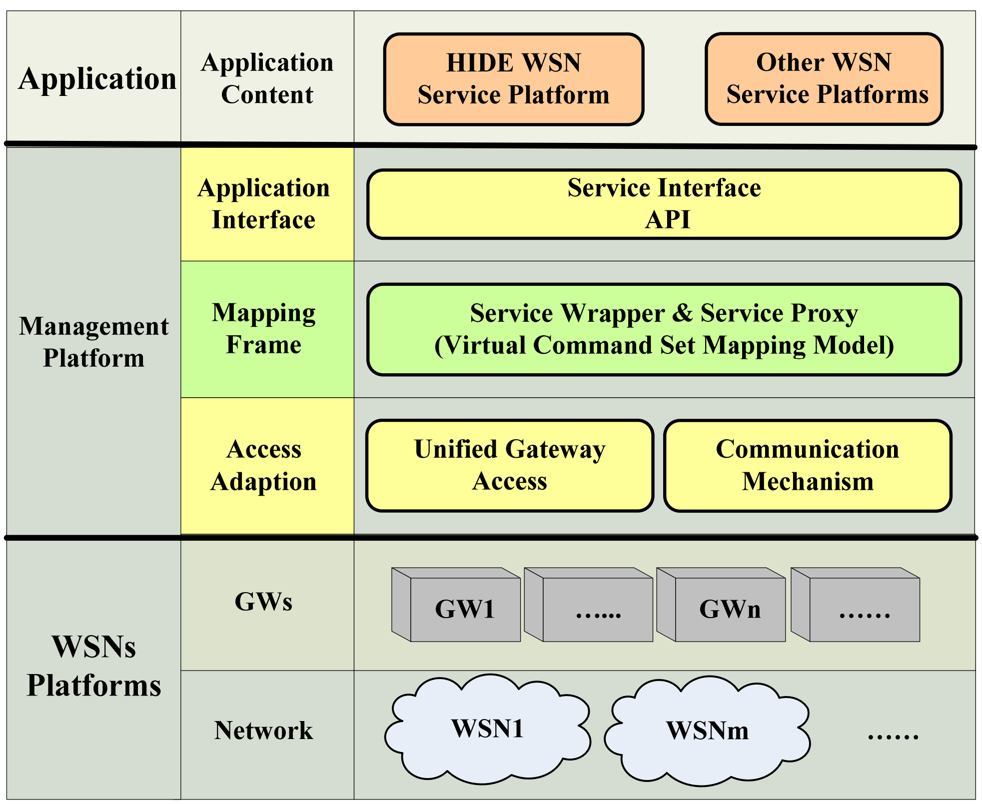


Figure 4.1 H-WSNMS System Logic Architecture

Mapping Fame and Access Adaption are key parts in the design and implementation of H-WSNMS, involving two main technologies as follows:

- Mapping Model Technology
- Unified Gateway Access Technology

4.2. Mapping Fame

4.2.1. Mapping Model Technology

During the design, the goal of Mapping Model is to map concepts, command elements and relationships from the virtual commands to the target command set in order to implement a service from Client.

- Conceptual Mapping: Conceptual mapping is the listing of all existing Virtual commands.
- Attribute mapping: This logical step is to identify similar attributes. At this level special attention has to be paid to synonyms, homonyms and the inherent context of attributes. Two attributes are said to be equal when they describe the same real world property.
- Content Mapping: Most mapping efforts tend to conglomerate content mapping with attribute mapping. Two values are said to be identical if they can be derived from one another. At the attribute level, equivalence between real world properties is established while the content level deals with how attribute values are derived from one another.

The complexity of any mapping effort is directly related to the complexity of these individual components.

4.2.2. Virtual Command Set Mapping Model

In previous traditional design, Command one-to-one Model was adopted in the WSN management system. The flexibility and reuse have been neglected and more efforts have been rightly directed at identifying and resolving mapping issues. In order to avoid those same pitfalls, the Virtual Command Set Mapping Model (VCSMM) multi-to-one-to-multi process must include rules and guidelines addressing these issues. For the solution to be flexible and scalable, the implementation of a valid Virtual Command Set multi-to-one-to-multi Mapping must be included:

- Virtual Commands: For any Service Component (SC) containing a list of independent enumerated Virtual Commands VC1, VC2…, VCn susceptible of being exchanged based on definition of VCC, there must be an exhaustive set VCS of unique enumerated values in the reference function model (MSA service component) such that VCS = {VC1,VC2…, VCn}. VC can be extended as more service components are added to the federation.
- Properties: For any Service Component containing a list of independent Virtual Command Attributes (VCA) referring the WSN gateway middleware information, with XML file format, VCA1, VCA2,…, VCAn susceptible of being exchanged based on the Attribute parameters, there must be an exhaustive set VCAS of attributes in the reference service function model such that VCAS = { VCA1, VCA2…, VCAn}. CAS can be extended based on the updation of this function component.
- Associated Concepts: For any set of Objects GWS, linked through a relationship describing the Target Command concepts TC1,TC2…, TCn, there must be an exhaustive set TCS of concepts in the reference WSN gateway model such that TCS = { TC1, TC2…, TCn}.
- Gateways: For real Gateway objects GW1, GW2…GWm susceptible of being exchanged according to Gateway Configuration information, there must be a set GWS of independent objects in the reference WSN platform model such that GWS = {GW1, GW2…GWm}. Objects can be added as new gateways join the federation.

This extended framework advocates the creation of a VCSMM during the implementation of Service function component. The main advantage of VCSMM is the creation of a series of information exchange requirements with a specific input/output command set and format to which all participating function models have to abide. It becomes, in fact, the common language spoken and understood by all members of a federation. In VCSMM, models interoperate through the VCSMM. Each model understands the language of the VCSMM and can therefore exchange information with any other model. A new model joining the federation must only interface with the VCSMM and it automatically interfaces with the rest of the federation.

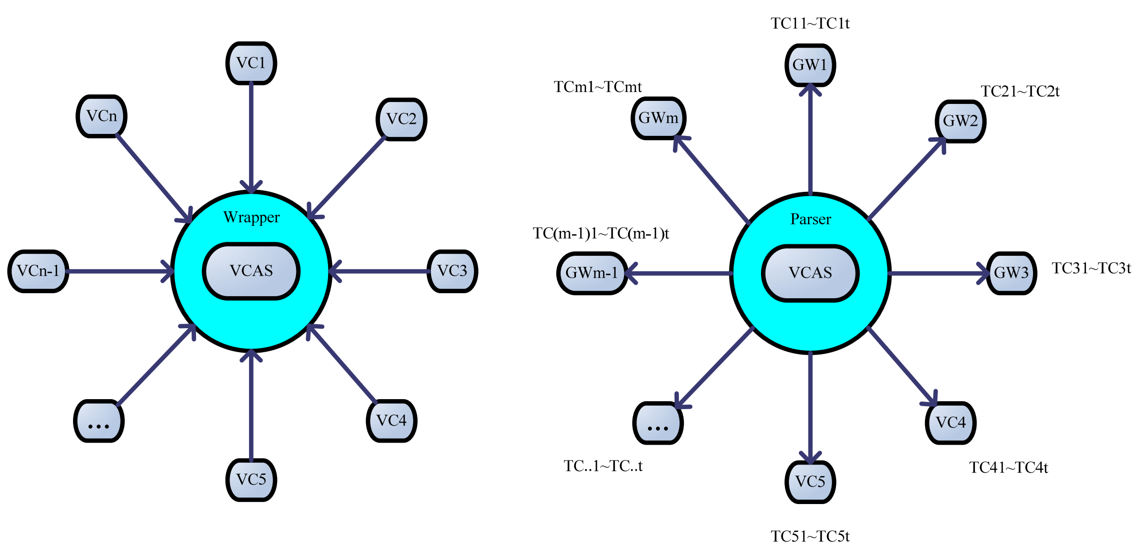


Figure 4.2 Virtual Command Set Mapping Module (VCSMM)

In the design of a heterogeneous WSNs management platform, the VCSMM reduces the number of total interfaces in a federation of N VC from N interfaces (one to one Model) in one-to-one model to 1 interface (multi to one to multi Model as in Figure 4.2, VCSMM). The left picture in Figure 4.2 describes the wrapping procedure of Virtual Commands {VC1,VC2,…VCn} formatted by Service Wrapper into VCAS (XML file); The right picture in Figure 4.2 illustrates us the parsing procedure of VCAS interpreted by Service Proxy into the scoped target concepts {TC1, TC2…, TCn} which can indentified and interpreted by heterogeneous WSN gateways.

Figure 4.3 shows us the VCSMM mapping flow in the red break line. In some sense, the VCSMM is a XML file Wrapping and Parsing Model from Virtual Command to Target Command to achieve multiple management functions accessing multiple WSN gateways, which is a kind of multi-to-one-to-multi process.

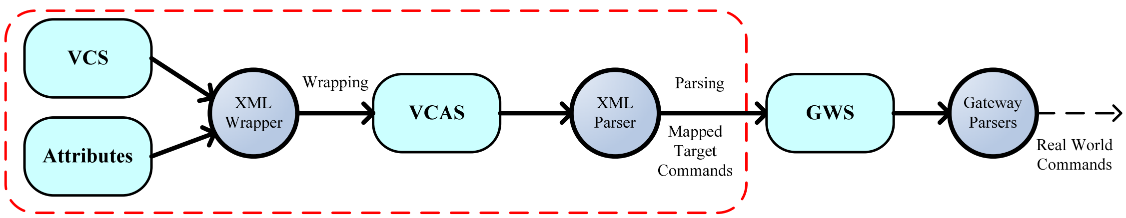


Figure 4.3 VCSMM Mapping Flow

4.2.3. VCSMM Application Case Discussion

During the application of VCSMM, considering providing Users a more friendly and humanized management and maintenance of WSNs, H-WSNMS system gives user several options to select:

- Saving Power Mode
- Speeding Mode
- Saving Power and Speeding Mode

Usually, when monitoring WSNs, we should consider the above three situations, for some certain type WSN platform, it is possible to use multiple gateways to cover all motes, for example, the Speeding Mode in Figure 4.4, it will give the multiple options (COM1, COM3, COM5, COM7) to select, every COMn stands for a Wireless Sensor Network, the purpose of this Mode is to quickly cover all possible motes in these four Wireless Sensor Networks if user can select all Wireless Sensor Networks. But in this mode, plenty of power in WSNs would be wasted and even lost without any benefit, although this way can improve and increase the data link speed to get more information such as the sampling data and other configuration and platform status than other modes, there exists a potential flaw: power wastage. On the other hand, if just considering power saving, only one WSN is selected, like the Saving mode (COM5) shown in Figure 4.4, the limited motes covered by one WSN can be visited, although this mode can save the power of this WSN, it cannot guarantee to access all possible motes, so its limitation is obvious. Based on the analysis on the previous two modes, the third mode “Saving Power and Speeding Mode” becomes a comprehension option for users, which provides maybe a better not the best option: COM3 and COM5 as shown in the picture. No matter which method is best option, it depends on user requirement, so system provides monitoring mode configuration to satisfy users. The mode configuration is described by XML file. The available WSN gateway power situation and cover performance should be done some statistics and represented in metadata file.

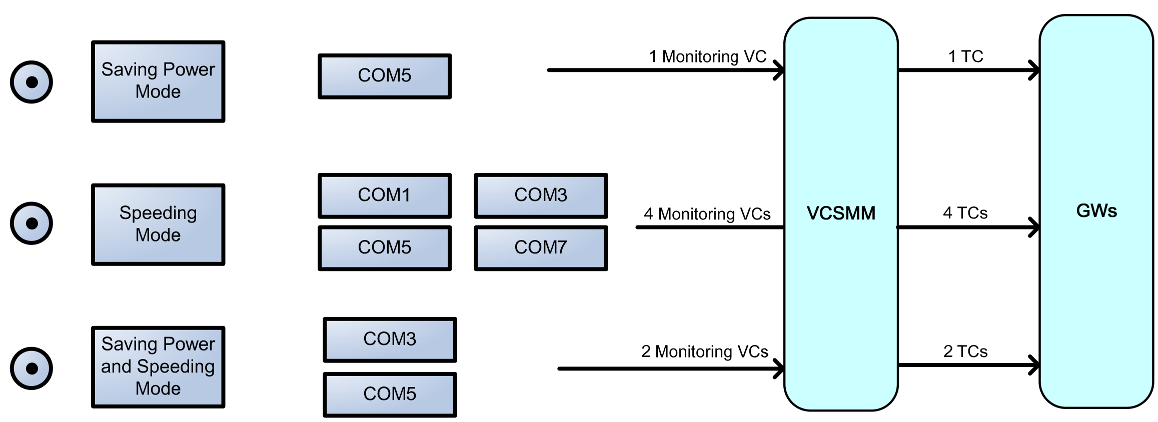


Figure 4.4 VCSMM Application

Figure 4.4 gives us an example to statement these three options:

- “Saving Power Mode” has only one gateway port (COM5)
- “Speeding Mode” has four gateway ports (COM1, COM3, COM5, COM7): recommend to select all at one time
- “Saving Power and Speeding Mode” has two gateway ports (COM3, COM5): recommend to select these two at one time

No matter how much the gateway ports to select, each function has one XML file created by Service Wrapper with the following format in Table 4.1:

Table 4.1 General Wrapped XML Format

Request XML Format	….
	<gateways>
	    <gateway>
	        <device>COM1<device>
	    ……
	    </gateway>
	    <gateway>
	        <device>COMi<device>
	    ……
	    </gateway>
	</gateways>
	….

After interpreted by Service Proxy, output the number of target command string is same as the number of gateways described in XML file.

Table 4.4 in section 4.4 describes the Gateway Monitoring Service Configuration XML file design, which provides a XML template of multi WSN platforms with multi available specific gateway communication Ports under above three different modes, displaying the system design flexible and scalable.

4.3. Access Adaption

4.3.1. Unified Gateway Access Technology

H-WSNMS provides a Unified Interface in the Unified Gateway Layer, completing a unified accessing of one or more gateways. Owning to the diversity of senor network services provided by various gateways and the variety of accessing protocol standard provided by different sensor networks, different type services have their own functions such as monitoring, reconfiguration, reprogram, data collection and so on.

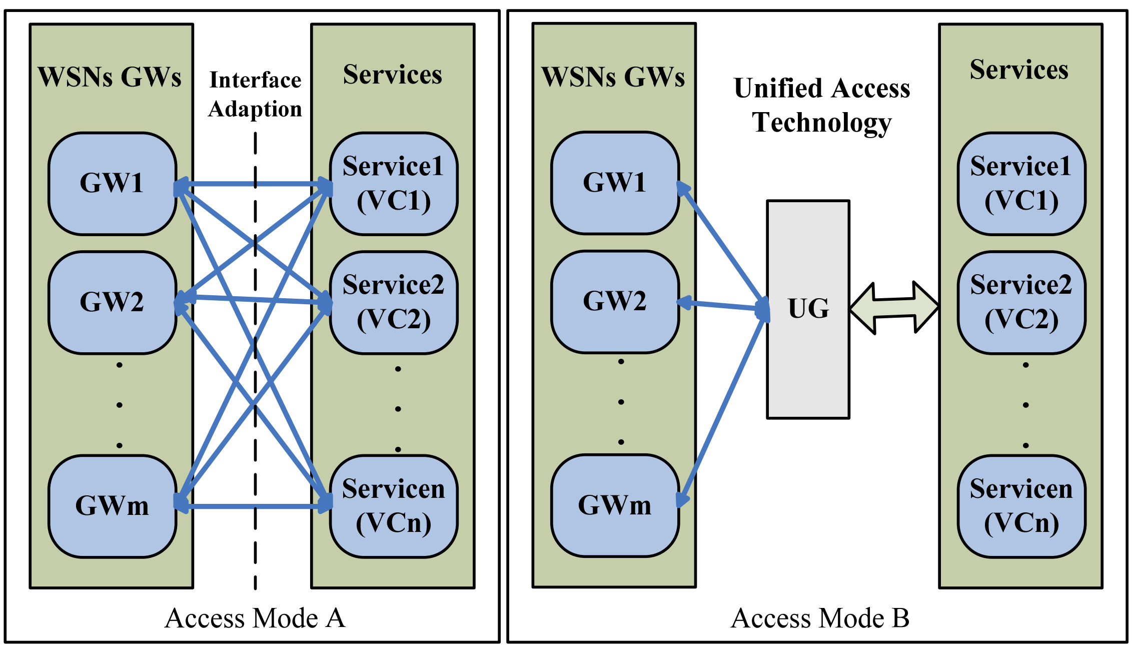


Figure 4.5 Comparison of Service Access Modes

Figure 4.5 displays the Traditional Service Access Mode and Unified Access Mode, Traditional Service Access Mode (Access Mode A) make the interface between Service Platform and WSN gateways over many, which obviously is not good for service extension and update. Otherwise, Unified Access Mode (Access

Mode B) can overcome the above defect and undoubtedly bring the following advantages to Service development.

We call this Unified Access Mode as Unified Gateway Interface, which is unique channel between the Service Management Platform and the Wireless Sensor Networks, being responsible for interoperating between different service and different service gateway and implementing the Adaptation of multi-service and multi-gateway. UG provides a means of real-time two-way communication between two data terminal installations: after the mapped target command outputs from Service Proxy, the UG MR component, UG Access component and Communication Mechanism component work together to complete the processing of the target commands' accessing heterogeneous WSNs, then the specific gateways sends the request to the WSN motes, through this way building a real-time interoperation.

- **Reduce the implication on platform services from changes of GW**: From the services in platform, what they face is not complex multiple gateway interfaces any longer, but a standard interface provided by a Unified Gateway (UG). Thus, when a gateway with updated version or a new gateway accesses, only revise and increase the corresponding configuration component (Gateway Configuration) in UG based on the updated or new gateway protocol, the platform services will not be impacted;
- **Improve the reliability of platform accessing**: After applying the Unified Access Technology to the service platform, UG becomes a unique channel between the Comprehensive Application Platform and Wireless Sensor Networks, which can better manage and monitor the relatively messy interfaces in Traditional Access Mode and more effectively improve the reliability of platform accessing;
- **Promote the quick development and deployment of services**: When exploring new services, need not consider the compatibility of multi-protocol based on a completed function Unified Gateway, thus, the period

of development and deployment of new applications is shortened along with;

- **Enhance the general applicability of developed services**: The development of new services does not involve the adaptable problem of the specific gateway, which enhance the applicability of services.
- **Reduce the number of the inner interface**: Reduces the number of total interfaces from N x M interfaces to M+1 interfaces, N is the number of the services, M is the number of gateways.

Based on the above research and analysis, there are several key points in the design and implement of UG:

- **UG Modular Design**: having characters such as unity, scalability and so on. UG is designed as a set of components, including Gateway Configuration component, Service Repository component, and Socket Communication component and so on.
- **API Encapsulation**: According to the access requirement, make corresponding adaption of this Unified Gateway interface.
- **Protocol Adaption**:
    - **Socket**: System adapted the Client-Server Socket Communication Model to pass the target command string(s) mapped in UG layer between MAS layer and the specific gateway(s) in Mote layer. The Code design of Socket Port is discussed in

4.3.2. Unified Gateway Access Model

Unified Gateway (UG) is one of the core components in H-WSNMS, one side, it links to the service platform, other side, and it communicates with different real wireless sensor gateways. UG adopts flexible Loosely-coupled Design thinking, satisfying the requirement of extension and updation. The whole running environment is divided into the following two parts:

- **Gateway Configuration**: a series of XML files which provide the information of gateway interactivity and real-time monitoring and control, in the future, the system developer can design a Web-based or MS Window-based Virtualization Tool to complete gateway configuration;
- **Gateway Access Loader**: Through this Loader, some certain gateway can be start-up, shut-down and configuration. When a gateway starts up, through gateway configuration component, the configuration information or the prescribed configuration files can be input manually.
- **Third-Part Gateway Interface**: For extension of other standard gateway interface, this interface can be extended by the future developer, which provides a flexible interface to other Wireless Sensor Management Services and Applications Platforms.

4.4. H-WSNMS Implementation

4.4.1. H-WSNMS Software Architecture Overview

A three-layer Architecture based on J2EE Frame is applied in the design of H-WSNMS Service Comprehensive Application Platform. Figure 4.6 displays H-WSNMS Software Architecture.

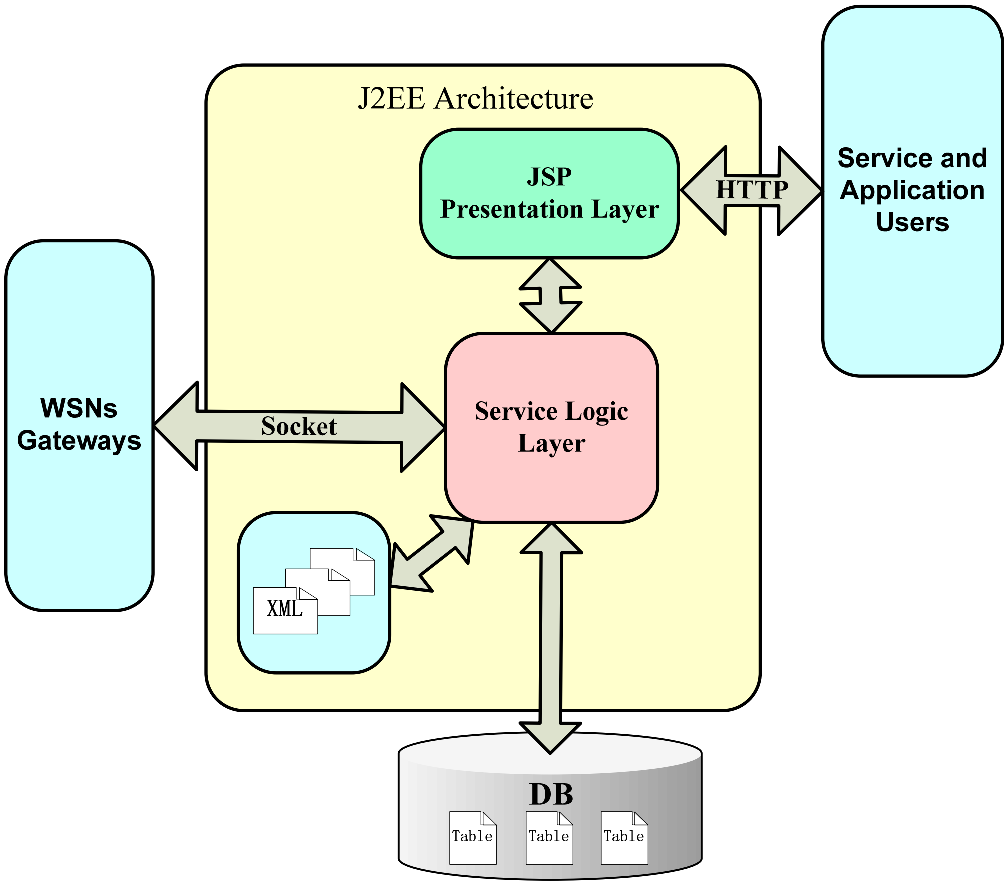


Figure 4.6 H-WSNMS Software Design

Service Logic Layer is responsible for the implementation of all logical functions in the whole management system, which is designed by Java Technology. JSP Presentation layer is responsible for the implementation of all Web pages such static User Interfaces and other dynamical web pages.

J2EE Framework in Web-based Management Platform has following features:

- Portability of Web-based component
    - Over different vendor platform
    - Over different operational environment
    - Portability, Scalability, Reliability
- Leveraging existing J2EE programming models for service implementation

- Easy to program and deploy
    - High-level Java APIs
    - Use existing deployment model

4.4.2. System User Interface Design

This section is mainly developed with JSP and Java Script technologies. There are some demos displayed by an instantiation in the Chapter 5.

4.4.3. XML Template and Definition

Based on the above the key technologies and core models, in this section, we will focus on the implementation of the whole system.

As we know, the design and implementation of VCSMM becomes the most important part in H-WSNMS system, one side, the Service Wrapper is responsible for wrapping the virtual commands, automatically creating XML template file(s) based on different Management Service Components; another side, the Service Proxy is responsible for interpreting the XML file into the target commands. The Table 4.2 is an example of wrapped XML template about Virtual Command Set and final Mapped Target Command String. This XML template is specific for of “Data Connection” Function, through which system can get the WSN Gateway information that is responsible for receiving the target command(s) and sending them to Mote layer and Database information which is responsible for storing the responded data from motes in WSNs.

Table 4.2 Wrapped XML Template File and Mapped Command String

Function	Data Collection Request XML File
Request Node XML Format	<?xml version="1.0" encoding="UTF-8"?> < Datacollreq > <gateways> <gateway> <gatewayname>XServe</ gatewayname> <gatewayid>05</ gatewayid> <serviceID>105100</serviceID > <device>COM5</device > <interfaceboard> MIB520</interfaceboard> <baudrate >57600</baudrate > <dbinfor> <dbserver>149.166.32.252</dbserver> <dbport>5432</dbport> <dbname>IDAM</dbname> <dbuser>tele</dbuser> <dbpasswd>12345678</dbpasswd> <databaseparsed>l</databaseparsed> <xmlfile> XmlStream.xml</xmlfile> <xmlp></xmlp> <xmlport>9005</xmlport> </dbinfor> </gateway> <gateway> …… </gateway> </gateways> </Dataconnreq >
Mapped Target Command String	xserve –s=COM5 –b=57600 –dbserver=149.166.32.252 –dbport=5432 –dbname=IDAM –dbuser=tele -l –xmlfile=XmlStream.xml -xmlp –xmlport=9005
Note	This is a **General and Extendable file** **Example**: **Available Command parameters** for XServer (**Refer XServe Users Manual, in which there is the detail introduction about various XCommand Arguments**) main parameters: xserve -s -b -dbserver -dbport -dbname -dbuser -l -xmlfile -xmlp –xmlport

After completing the mapping procedure, Socket in UG Layer has been applied as the communication method between the MAS layer and Mote Layer. A different type function has a different communication port for it. We design a socket port management mechanism to achieve this aim. The method is described as following:

As mentioned in section 3.3.1, in which the Table 3.1 shows us the main Command Category and Specification of VCS. The Table A.1 in Appendix A gives us the detail definition of various parameters involved in the whole design of H-WSNMS, including a series of code rules such as the code definition of WSN platform, the code definition of WSN gateway and so on. The Based on the Table A.1 or the following Table 4.2, we design the Definition of ServiceID, or called as VCID, and Socket Port.

Table 4.3 Specification of Code

Parameters	Definition
PlatformID (*extendable*)	PlatformNo. N: 1~9
GatewayID (*extendable*)	XX: 01~99
GatewayCode (*extendable*)	Y:1~9
VCS Code (*extendable*)	00: H_DataColl
	10: H_Monitoring
	20: H_Config
	60: H_Repro
	70: H_others

ServiceID code is composed of 6 digital numbers, which is used to tag each VC:

PlatformID+GatewayID+GatewayCode+ VCC No.

Socket Port Code is made up of 4 digital numbers, which is used to tag Socket Port and the XML file name:

PlatformID+ GatewayCode + VCC No.

Following the code rule in Table A.1 or Table 4.2, take “Data Collection” Function based on XServe provided by MoteWorks platform with specific communication port COM5 as an example:

ServiceID Code: 1 05 1 00

1: PlatformID: MoteWorks produced by Crossbow

05: GatwayID: XServe (COM Port=COM5)

1: Gateway Code of XServe

00: Data Collection Service VC code

105100: DataCollection Function based on XServe provided by MoteWorks platform with communication port COM5.

Socket Port Code: 1 1 00

1: Platform Code or PlatformID: MoteWorks produced by Crossbow

1: Gateway Code of XServe

00: H_DataColl: Data Collection Service VCS code

1100: Socket Port

1100Req.xml: Data Collection Function XML file name

Each application function for the same WSN platform has unique Socket Port, so we name the wrapped XML file name of this function as Socket Port+"Req.xml" and store this XML file into the corresponding folder with same name as the name of WSN platform under the given path. The Service Proxy will automatically find this XML file with name "Socket Port+"Req.xml" " to interpret and map it to the Target Command string.

The code of ServiceID and the code of Socket Port are not limited the 6 digital numbers or 4 digital numbers, they can be extended according to design requirement, From Table A.1 or Table 4.2, the PlatformID, GatewayID, GatewayCode are extendable and the extension of them can be completed in the corresponding configuration files, which displays the scalability and flexibility of system design.

In MSA layer, another component: Gateway Service Configuration component, provides a series of XML files as shown in Table 4.3, Table 4.4 and so on. The Table 4.3 describes Mote Data Collection Query Service information, including sensor location, sensor status, sensor type, sampling rate, collection rate and so on, the Table 4.4 describes available specific communication port for some certain WSN platform under three different Monitoring modes discussed in section 4.2.3. These XML files can be extended according to system sensor data management requirement. This design is very flexible, based on which the future system service developers can create new services.

Table 4.4 Data Collection Service Configuration XML Template File

Function	Data Collection Service Configuration XML File
Config XML Format	<?xml version="1.0"?> <sensorNet> <BasicInformation> <state>Indiana</state> <county>Indiana1</county> <siteName>Y_Indianapolis</siteName> <NetType>Other</NetType> <OriginalPoint Longitude="86" Latitude="39"/> </BasicInformation> <Scope> <North Longitude="86" Latitude="39" /> <South Longitude="86" Latitude="38" /> <East Longitude="87" Latitude="38" /> <West Longitude="87" Latitude="39" /> </Scope> <SensorNodes> <SensorNode> <NodeId>1465</NodeId> <NodeLocation x-coordinate="1" y-coordinate="1"/> <sensorType>model1</sensorType> <sensorStatus>work</sensorStatus> <canMeasure> <Parameter> <BaseTime>00:00:00</BaseTime> <SampleRate>5000</SampleRate> <CollRate></CollRate> </Parameter> </canMeasure> </SensorNode> <SensorNode> ……. </SensorNode> </SensorNodes> </sensorNet>
Note	**This is a General and Extendable file**

Table 4.5 Monitoring Service Configuration XML Template File

Function	Monitoring Service Configuration XML File
Config XML Format	<?xml version="1.0" encoding="UTF-8"?> <MonitoringServiceConfig> <Platforms> <Platform> <PlatformName>MoteWorks</PlatformName > <GatewayName>XServe</GatewayName > <Modes> <Mode>Power</Mode> <AvailablePort>COM5</ AvailablePort > <Mode>Speed</Mode> <AvailablePort>COM1, COM3, COM5, COM7</ AvailablePort > <Mode>PowerSpeed</Mode> <AvailablePort>COM3, COM5</ AvailablePort > </Modes> </Platform> <Platform> <PlatformName>Praticle</PlatformName > <GatewayName>xxxx</GatewayName > <Modes> <Mode>Power</Mode> <AvailablePort>xxxx</ AvailablePort > <Mode>Speed</Mode> <AvailablePort>xxxx, xxxx, xxxx, xxxx</ AvailablePort > <Mode>PowerSpeed</Mode> <AvailablePort>xxx, xxx</ AvailablePort > </Modes> </Platform> <Platform> …… </Platform> </ Platforms > </ MonitoringServiceConfig >
Note	**This is a General and Extendable file**

4.4.4. Data Structure and Definition

Considering that some certain function such as “Data Collection” function need to synchronize the wireless sensor data, and “Configuration” function maybe update platform or WSN gateway status information, these dynamical data and status information management should stored in the system own database. The HWSNMS DB is responsible for storing and maintaining these data and configuration information, which is designed and implemented through using the PostgreSQL database technology.

Some Datatables are described in Appendix D.

CHAPTER 5. H-WSNMS CASE STUDY

5.1. Experiment Hardware

In this chapter, we will discuss the H-WSNMS XServe [7] Instantiation based on HIDE system in detail. Before the discussion of H-WSNMS Application design, we should introduce the experiment environment.

Hardware is composed of three parts: Mote, Sensor board and Programming board, as shown in the Figure 5.1.

Mote Type: **Micaz**

- Processor ATmega 128L
- Freq. 2400 MHz to 2483.5 MHz
- Range Outdoor/indoor 75 m to 100 m/20 m to 30 m
- Onboard Sensor /extend board None /Yes

Sensor Board: **MTS310**

- Light, Temperature, Microphone, Buzzer, 2-axis Accelerometer and 2-axis Magnetometer Sensor
- Compatible with IRIS/MICAz/ MICA2 Processor/ Radio Boards

Gateways: **MIB520+Mote**

- Programming board MIB520 (Upload NesC file to mote (wire)
- Communicate with mote (wireless)
- Send NesC file to mote (wireless)
- Collect mote's data

Note:

- MIB520: Programming board
    - o Upload NesC file to mote (wire)
- MIB520+Mote: Base Station

  - o Communicate with mote (wireless)
  - o Send NesC file to mote (wireless)
  - o Collect mote's data
- MIB520+Mote+PC/Server
  - o Store data to database

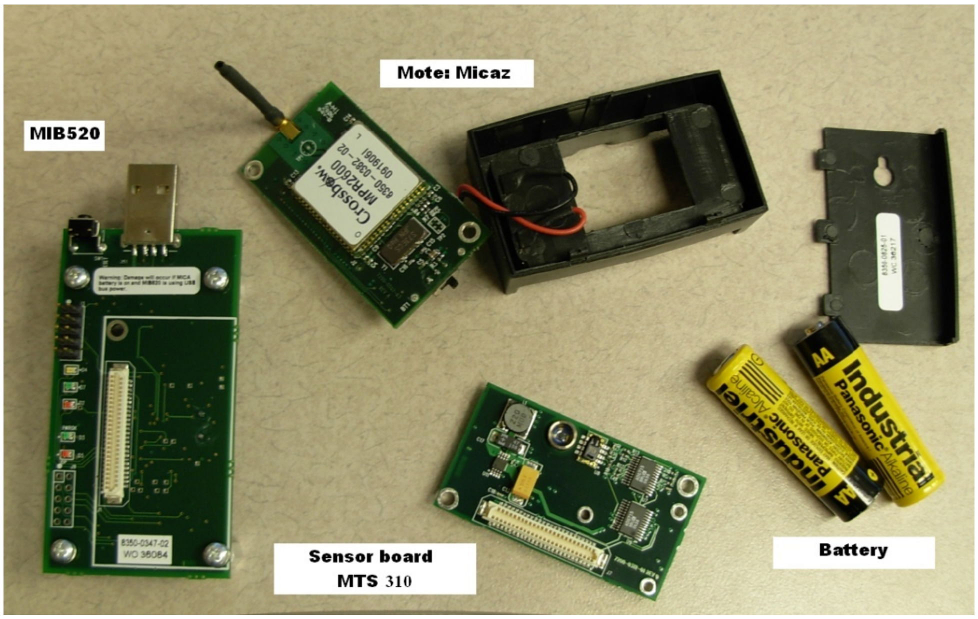


Figure 5.1 Mote Hardware

The Table 5.1 shows the information of some Sensor boards and motes.

Table 5.1 Sensor Boards and Motes

Crossbow Part name	Motes supported	Sensors and Features
MTS101CA	MICAz,MICA2, MICA	Light, temperature, prototyping area
MTS300CA MTS300CB	IRIS, MICAz MICA2, MICA	Light, temperature, microphone, and buzzer
MTS310CA MTS310CB	IRIS, MICAz MICA2, MICA	Light, temperature, microphone, buzzer, 2-axis accelerometer, and 2-axis magnetometer
MTS400CA MTS400CB MTS400CC	IRIS, MICAz MICA2	Ambient light, relative humidity, temperature, 2-axis accelerometer, and barometric pressure
MTS420CA MTS420CB MTS420CC	IRIS, MICAz MICA2	Same as MTS400CA plus a GPS module
MTS510CA	MICA2DOT	Light, microphone, and 2-axis accelerometer
MDA100CA MDA100CB	IRIS, MICAz MICA2	Light, temperature, prototyping area
MDA300CA	IRIS, MICAz MICA2	Light, relative humidity, general purpose interface for external sensors
MDA320CA	IRIS, MICAz MICA2	General purpose interface for external sensors
MDA500CA	MICA2DOT	Prototyping area

5.2. Software Platform

Figure 5.2 shows us the Three-tier software architecture instantiated based on Crossbow XServe.

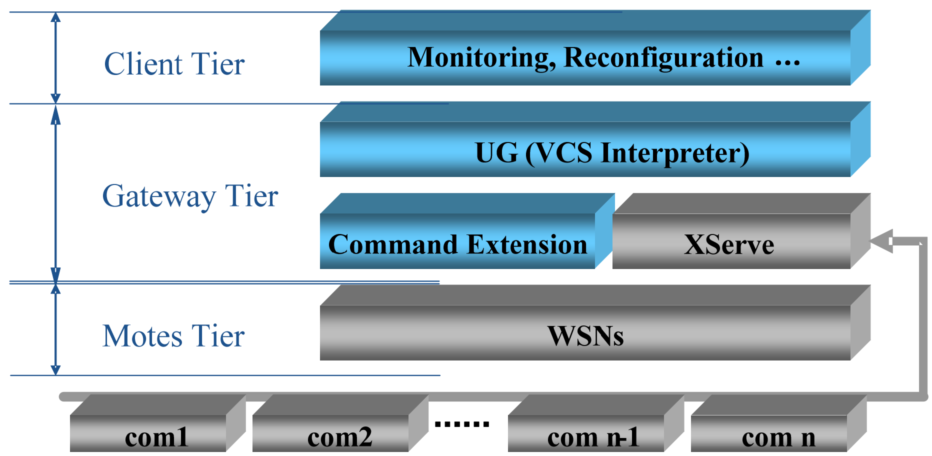


Figure 5.2 Three-tier architecture instantiation based on XServe

H-WSNMS Software Platform Deployment is composed of the two distinct software layers, Client layer and Gateway layer. In above three-tier architecture, the motes tier belongs to the hardware content we have introduced in section 5.1. In the following two sections, we will discuss the Clients Tier and Gateway Tier respectively.

5.2.1. Client Tier

The Client Tier provides the user visualization software and graphical interface for managing the network and retrieving sensor data.

In H-WSNMS system, we can directly acquire data through accessing Wireless Sensor Network, which is an advantage displayed in the function “Data Collection Function”, and manage the heterogeneous wireless sensor networks, which is another advantage described in several familiar functions in the wireless sensor networks management such as Monitoring, Configuration, Reprogram and Data Collection and so on. In H-WSNMS, Client Tier is designed and implemented with JSP and JavaScript Technologies.

5.2.2. Specific Gateway Middleware

The Gateway Tier is an always-on facility that handles translation and buffering of data coming from the wireless network and provides the bridge between the wireless motes and the web-based Applications. In this Case, XServe is a specific gateway middleware, as described in Figure 5.3, wherein XServe and XOtap are server layer applications that can run on a PC or Stargate.

Crossbow XServe [7] is the glue layer that connects the wireless sensor network to enterprise or industrial networks through standard XML. Due to the low-power and memory footprint requirements in wireless sensor networks, communication is streamlined through message formats and network protocols.

A local database allows XServe to store and process sensor and network information. Integration with back-end monitoring, control and management systems delivers the full value of wireless sensor networks to enterprises and makes the connection of the physical world with the internet a reality.

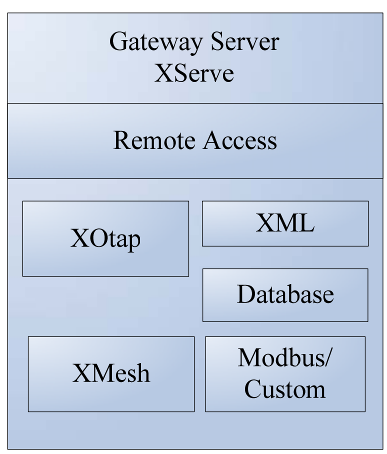


Figure 5.3 Gateway Middleware: XServe

In higher level services for enterprise applications, Crossbow XServe can be configured to parsing sensor packets into a series of name values pairs giving richer meaning to the sensor data.

Crossbow sensor applications allow users to query state variables. This feature is called XCommand [7]. XServe provides two interfaces for enterprise applications to send commands to the Mote Layer using XCommand. Users can send and receive XCommands using XServeTerm, a terminal command application. Applications can send and receive XCommands using an XML RPC interface. XCommand and XServeTerm are commonly and regularly used in the Management Application Functions such as Monitoring, Configuration and Data Connection and so on.

XServe [8] also implements the Over-the-air Programming (OTAP [8]) function, which feature allows users to reprogram any Mote within the XMesh [8] network. OTAP allows one or more Motes to receive new programming images from XServe (via XOtap), a server-side application via wireless communication. The XOtap [8] application is a server side tool that works, either with XServe or directly connected to the serial port of the XMesh Gateway, to communicate with the XMesh network. It resides in the XServe Layer (in a remote or local server or Stargate) of the XMesh Network landscape. Users use XOtap to download program images to the Motes by having the application first read an IHEX image file name and a list of Motes to download. Then the image is downloaded to each Mote.

Appendix B represents a series of various available command parameters referring the XServe Manual [7] and Mesh Manual [8] provided by CrossBow MoteWorks. Appendix C makes some definitions for different functions based on the Code Rule in Appendix A and available command parameters statement in Appendix B. Based on these XServe features, several web-based WSNs management functions have been designed and developed, which will be introduced in the following section.

Crossbow's XServe is used as one instance of specific WSN platform's gateway technology to be handled by the Unified Gateway in the H-WSNMS architecture as shown in Figure 5.2. We demonstrate the design idea through developing several management components: Monitoring, Reconfiguration, Reprogram and so on. From the client tier point of view, these management components execution details are hidden from users. In general, partial functionality of commands required by management components can be mapped to the Target Command already provided by XServe.

5.3. Main Functions Overview

This section will discuss the main functions of H-WSNMS based on CrossBow XServe.

In this system, there are several main functions:

- Monitoring: supervises the status of Wireless Sensor Networks
- Configuration: completes Mesh Motes Configurations with XCommands
- Reprogram: uploads the OTAP program to the motes
- Data Collection: retrieves and displays the wireless sensor data from HIDE own sensor data resource

The general control and status information flow in H-WSNMS system has been illustrated in Figure 3.2, the following sections we will one by one discuss the control and status information of functions such as Monitoring, Reconfiguration and Reprogram and so on.

The screenshot shown in the Figure 5.4 is system user profile of H-WSNMS WSN Management System, which provides a series of functions such as Monitoring, Configuration, Reprogram and Data Collection and so on.

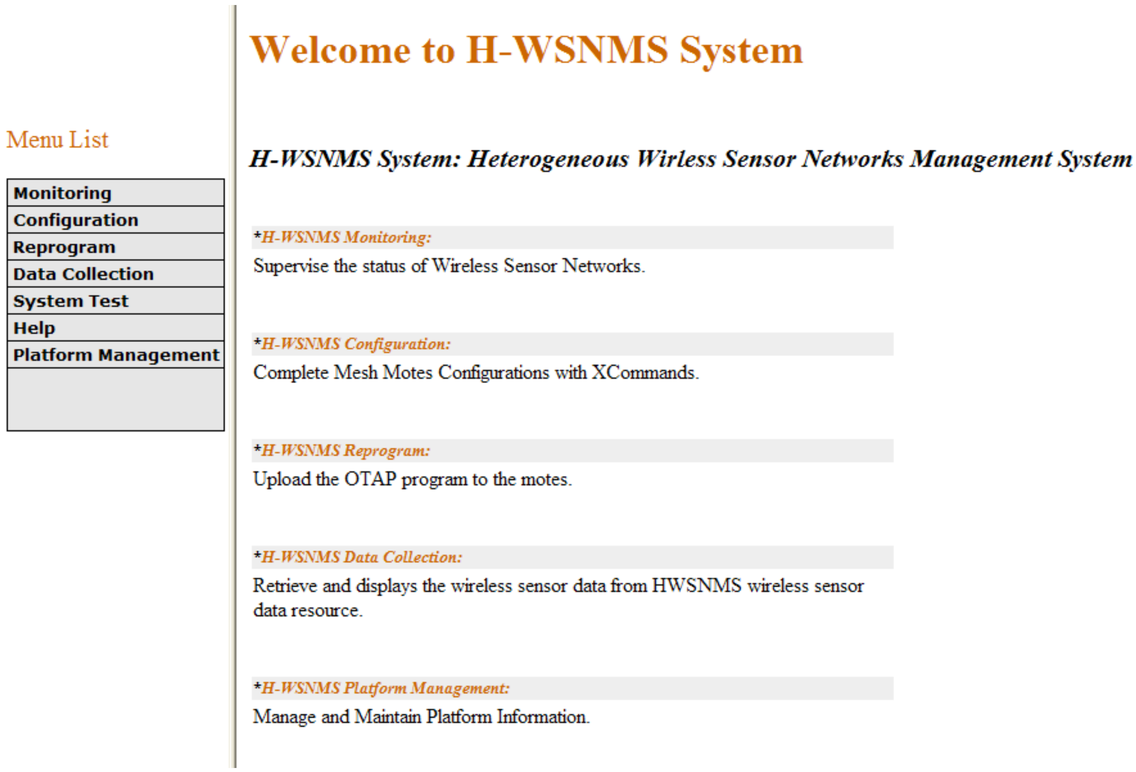


Figure 5.4 User Profile of H-WSNMS

5.3.1. Monitoring Function and Demo

Figure 5.5 shows us the Logical Flow of Monitoring function.

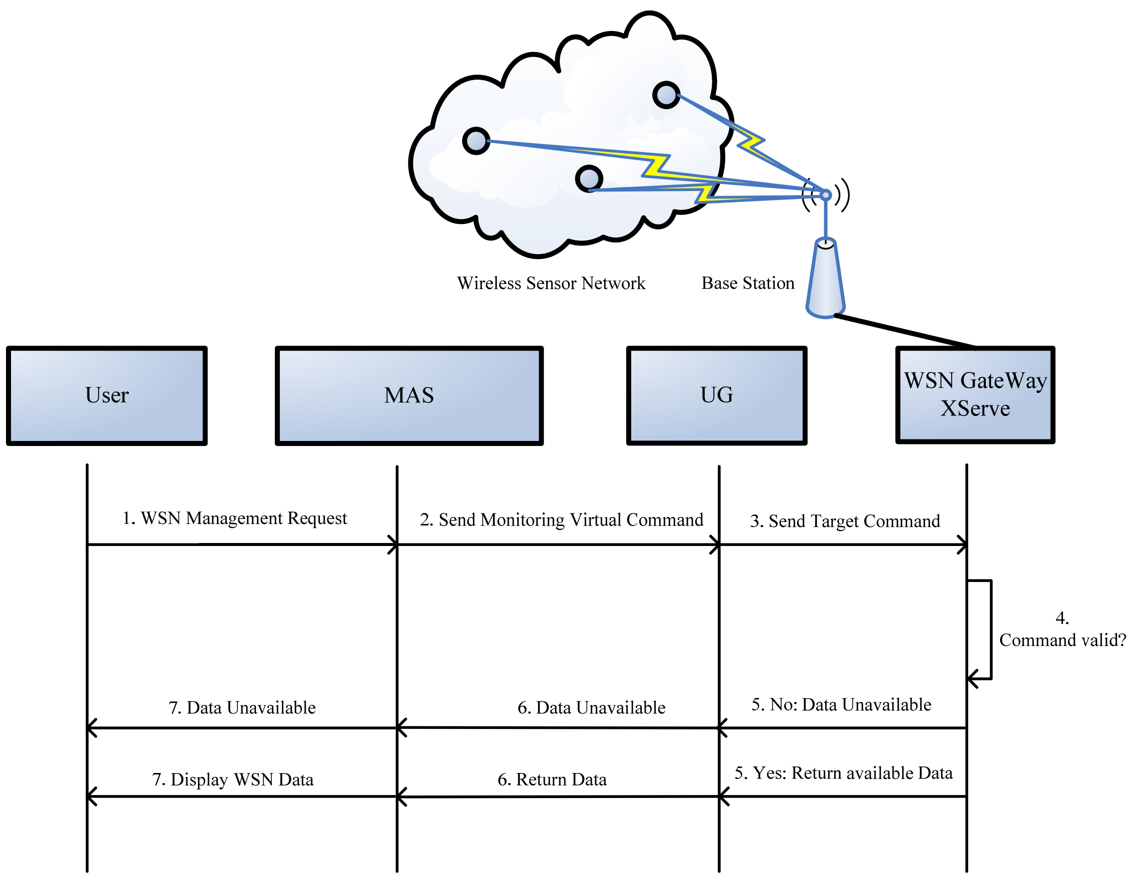


Figure 5.5 “Monitoring” Command Logical Flow

Function: User can use this function to view the real-time sensor data.

Flow Description:

When Users enter WSN Management system, Users send the “Monitoring” function request, which will be wrapped to the virtual command string package, then is interpreted and mapped to target command string and is sent to XServe, then XServe judges whether the command string is valid; If not, return the information about unavailable data to users, if yes, return the available data to users.

Monitoring Request XML File and Mapped Result:

Table 5.2 Monitoring Request XML File and Mapped Command String

Function	Monitoring Request XML File
Request Node XML Template	<?xml version="1.0" encoding="UTF-8"?> <Monitoingreq> <gateways> <gateway> <gatewayid>05</ gatewayid> <serviceID>105110</serviceID > <gatewayname>XServe</ gatewayname> <device>COM5</device > <interfaceboard>MIB520</ interfaceboard > <baudrate >57600</baudrate > </gateway> <gateway> …… </gateway> </gateways> </Monitoingreq >
Mapped Target Command String	e.g XServe –device=COM5 –baudrate=57600
Note	**This is a General and Extendable file** **Example**: **Available Command Parameters for XServe** (**Refer XServe Users Manual [7], in which there is the detail introduction about various Command Arguments**) XServe –device –baudrate

Function Information Description:

Monitoring Service “Monitoring” based on XServe provided by MoteWorks platform with communication port COM5.

Service Code: 1 05 1 10

1: MoteWorks PlatformID

05: Device: GatwayID (COM port=COM5)

1: Gateway Code of XServe

10: H_Monitoring: Monitoring Service (VC Code)

Socket Port Code: 1 1 10

1: Platform Code or PlatformID: MoteWorks produced by Crossbow

1: Gateway Code of XServe

00: Monitoring Service (VCS Code)

1110: Socket Port

1110Req.xml: Monitoring Function XML template file name

Note: the code rules and definitions refer to the Appendix A-C.

Demo:

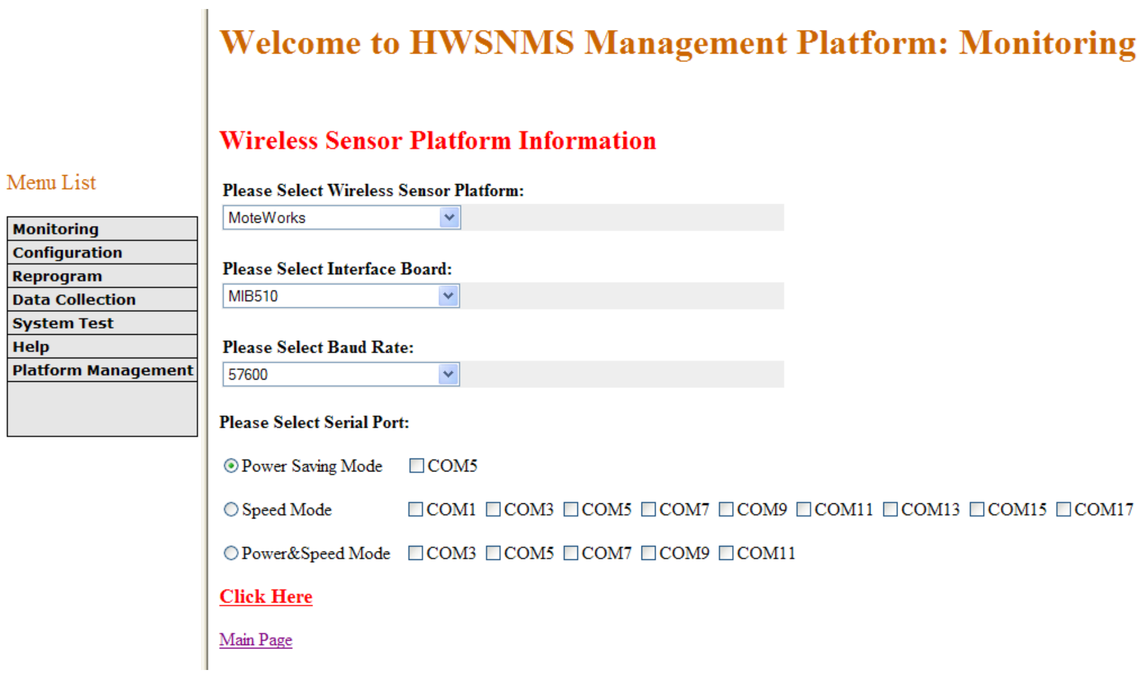


Figure 5.6 “Monitoring” UI

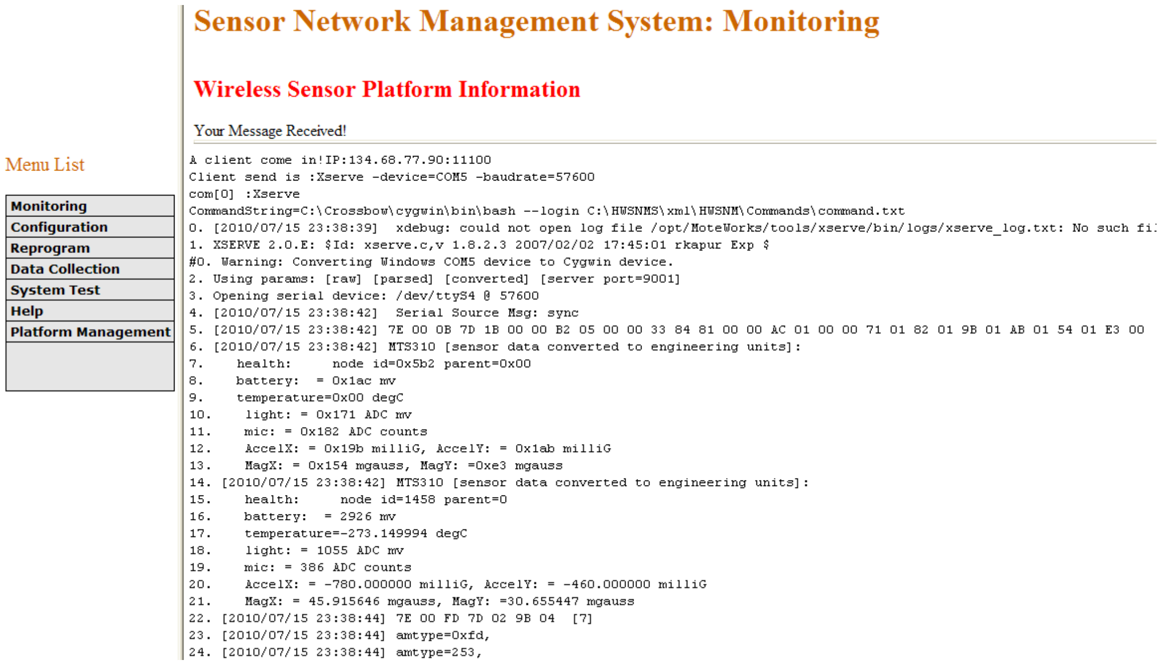


Figure 5.7 Demo of “Monitoring”

5.3.2. Configuration Function and Demo

Figure 5.8 shows us the Logical Flow of Configuration Function.

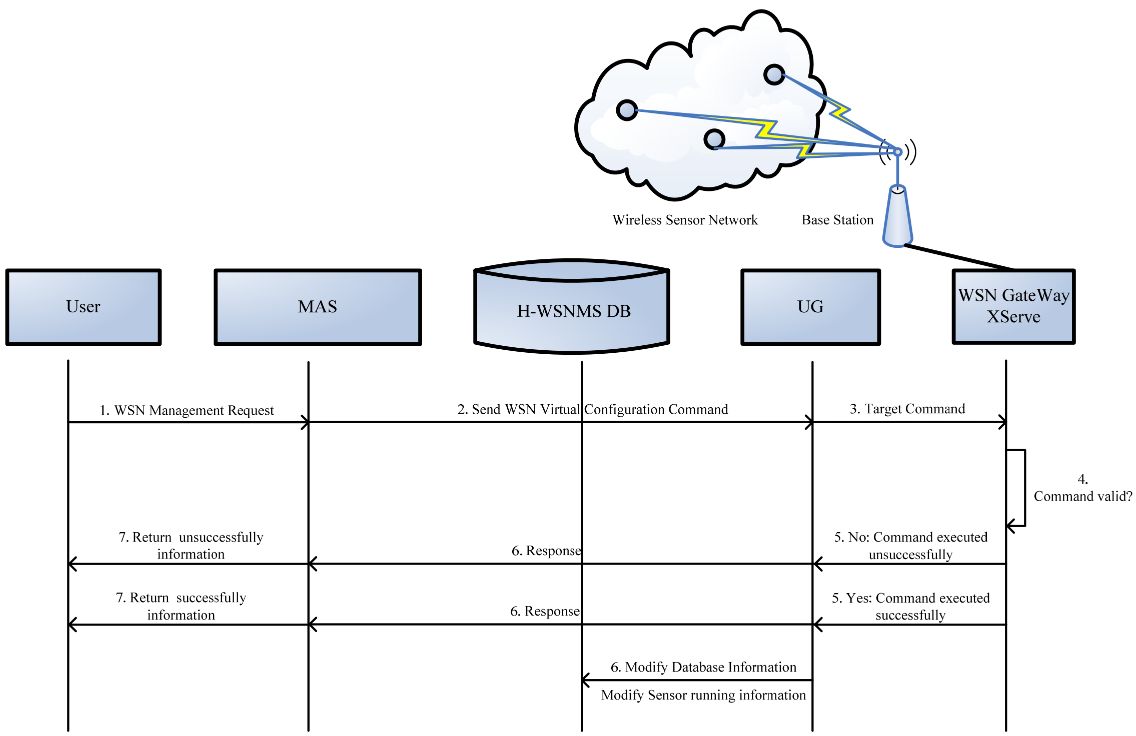


Figure 5.8 “Configuration” Command Logical Flow

Function: User can send and receive XCommand to complete the configuration using XServeTerm.

Flow Description:

When Users enter WSN Management system, Users send one “Configuration” function request, which will be wrapped to the virtual command XML package, then is interpreted and mapped to the target command string(XCommand string) and is sent to XServe, then XServe judges whether the target command string is valid or not; If not, return the information about unavailable data to users, if yes, return the available data to users, at the same time, the updated related information about platform or WSN gateway status automatically is stored into the H-WSNMS own database.

Configuration Request XML File and Mapped Result:

Table 5.3 Configuration Request XML File and Mapped Command String

Function	Configuration Request XML File
Request Node XML Template	<?xml version="1.0" encoding="UTF-8"?> <Configurationreq> <gateways> <gateway> <gatewayname>XServe</ gatewayname> <gatewayid>05</ gatewayid> <serviceID>105121</serviceID > <device>COM5</device > <interfaceboard>MIB520</ interfaceboard > <baudrate >57600</baudrate > <xserveterm> xserveterm.exe</xserveterm> <xcommands> <reconfiguration> <xcommand> get_config</xcommand> <destinationnode>1458</destinationnode> <update></update> </reconfiguration> <powermanagement> <pmstatus></pmstatus> <pmdestinationnode></pmdestinationnode> </powermanagement> </xcommands> </gateway> <gateway> …… </gateway> </gateways> </Configurationreq >
Mapped Target Command String	e.g: Xserve –s=COM5 –b=57600 Xserveterm> get_config 1458
Note	**This is a General and Extendable file** **Example**: **Available Command Parameters for XServe** (**Refer XServe Users Manual [7], in which there is the detail introduction about various XCommand Arguments**) Reconfiguration includes following xcommands H_ReConfig_GID set_default_group <group id> H_ReConfig_GetID get_config <destination address> H_ReConfig _SetID set_nodeid <destination address> <new node id> H_ReConfig _SpRate set_rate <destination address> <new

	rate> H_ReConfig _CRate set_collection_rate <destination address> <new size> H_ReConfig _ECollect set_manual_collection <destination address> <Flag> Power Management includes following xcommands H_PM_WAKEUP wake <destination address> H_PM _SLEEP sleep <destination address> H_PM _RESET reset <destination address> H_PM _SHUTDOWN xserve.shutdown

Function Information Description:

Configuration Service "Set NodeID" based on XServe provided by MoteWorks platform with communication port COM5.

Service Code: 1 05 1 22

1: MoteWorks PlatformID

05: Device: GatwayID (COM port=COM5)

1: Gateway Code of XServe

22: H_ Config_Reconfig_GetID: Set NodeID Service (VC Code)

Socket Port Code: 1 1 20

1: Platform Code or PlatformID: MoteWorks produced by Crossbow

1: Gateway Code of XServe

20: Configuration Service (VCS Code)

1120: Socket Port

1120Req.xml: Configuration Function XML file name

Note: the codes rule and definitions refer to the Appendix A~C.

Demo:

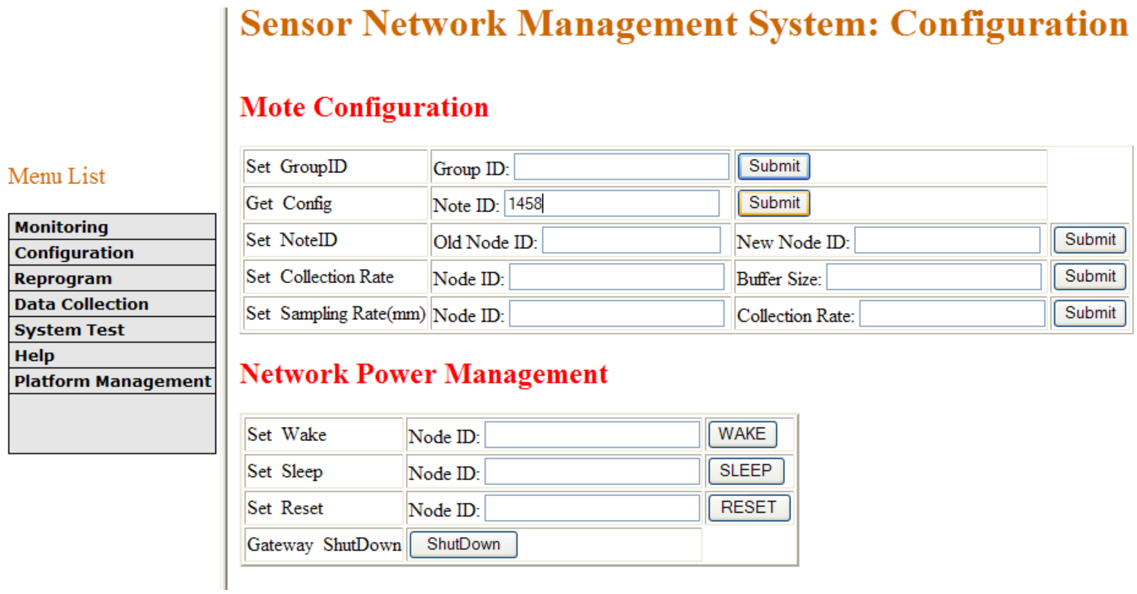


Figure 5.9 “Configuration” UI

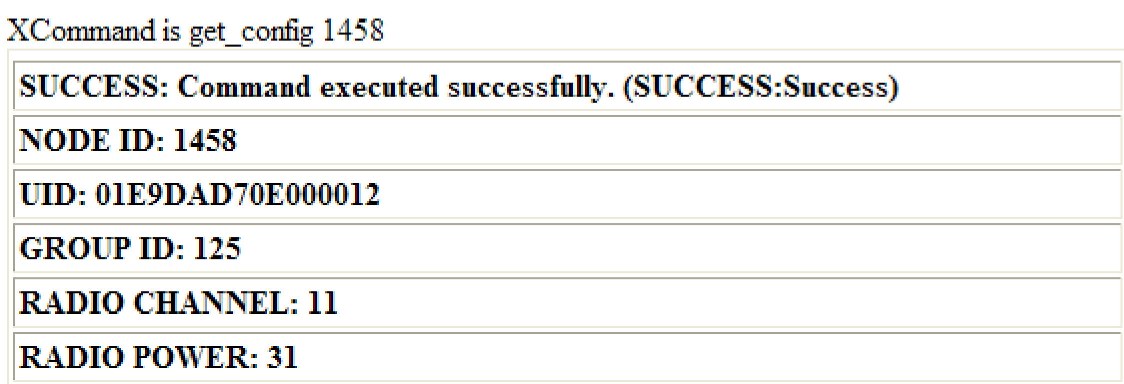


Figure 5.10 Demo of “Get Config”

5.3.3. Reprogram Function and Demo

Figure 5.11 shows us the Logical Flow of the Reprogram Function.

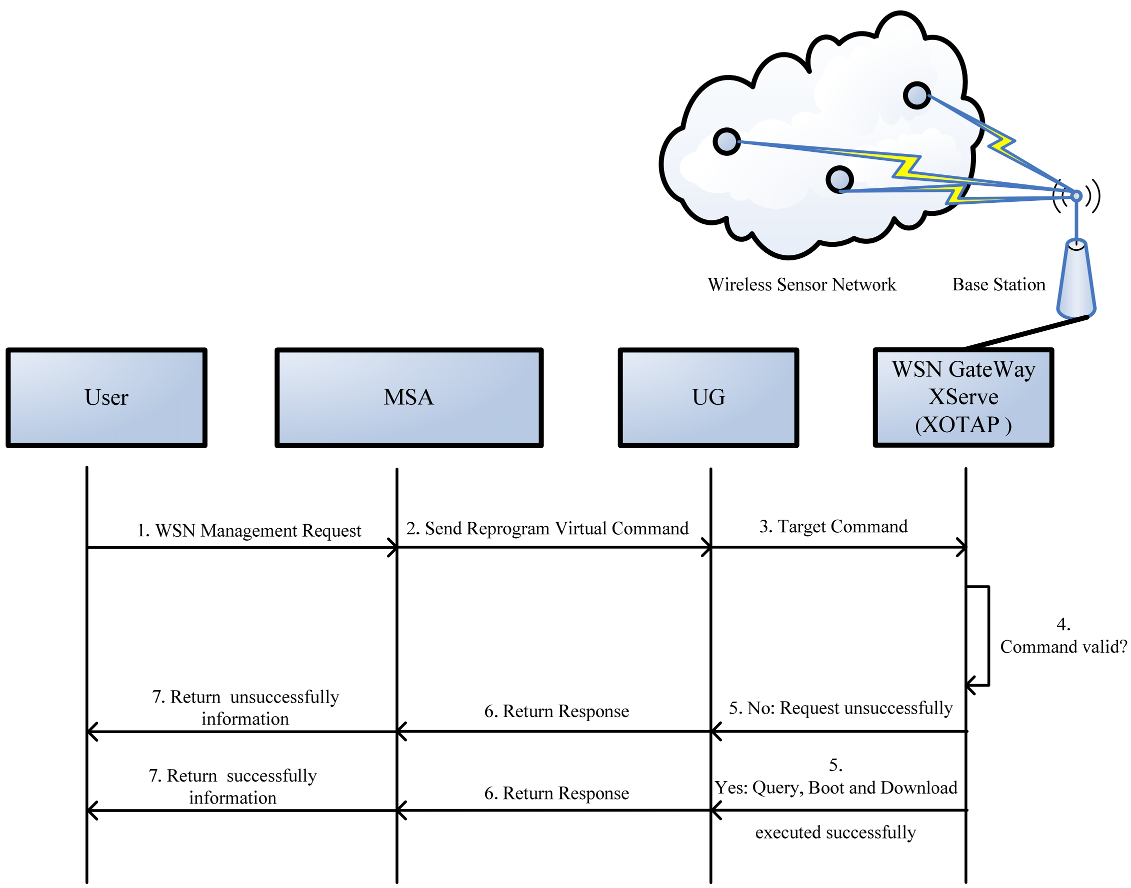


Figure 5.11 “Reprogram” Command Logical Flow

Function: Query, Boot and Download program to the motes through OTAP method with format IHEX.

- **Query**: users can optionally query a node when it is running the OTAP Image to get information about different slots.
- **Boot**: reboot all chosen nodes to OTAP specified Image.

- **Download**: specify the nodes we want to program and specify the slot. Select the binary image of the app (main.ihex), which is implemented and compiled by NesC language. As the OTAP progresses, you will see the report in terms of number of pages downloaded into the flash.

Flow Description:

When Users enter WSN Management system, Users send the “Reprogram” function request, which will be wrapped to the virtual command string XML package, which is interpreted and mapped to the target command string, after XOTAP receives the target command string and judges whether this mapped command string is valid or not; If not, return the unsuccessful information to users, if yes, return successful information, thus, users can use reprogram function successfully to upload the programming into motes in WSNs.

Reprogram Request XML File and Mapped Result:

Table 5.4 Reprogram Request XML File and Mapped Command String

Function	Reprogram Request XML File
Request Node XML Format	<?xml version="1.0" encoding="UTF-8"?> <Reprogramreq> <gateways> <gateway> <gatewayid>05</ gatewayid> <vcid>110161</vcid> <COMport>COM5</COMport> <baudrate > 57600</baudrate > <interfaceboard>xserve</interfaceboard> <xotap> xotap.exe</ xotap> <commands> <ip:port> <cmd>-sf</cmd> <ip> localhost</ip> <port>9001 </port> <ip:port> <image_number> <cmd>-i</cmd> <number>2</number> </ image_number> <boot> <cmd>-p</cmd> <image_number> </image_number> </boot> <query> <cmd></cmd> </query> <load> <cmd></cmd> <file>C:/main.exe.ihex</file> </load> <threshold> <cmd>-v</cmd> <vantage>2.7</vantage > </threshold> </commands> <modes> <mode>1458</mote> </modes> </gateway> <gateway> ……

	</gateway> </gateways> </Reprogramreq >
Mapped Target Command String	e.g C:/Crossbow/cygwin/opt/MoteWorks/tools/xotap/bin.cygwin.x86/; xotap.exe –I 2 -p -v 2.7 -sf localhost:9001 1458
Note	**This is a General and Extendable file** **Available Command Parameters for XServe** (**Refer XMesh Users Manual [8], in which there is the detail introduction about various XOTAP Command Arguments**) -f <image_file> Download the file. -i <image_number> Image number -q Query the Mote status -v <threshold> Download if the voltage is above the threshold (default 2.7v) -p <image_number> Boot the image number. -sf <ip:port> XServe host/port (default to localhost:9001) -c <COM port> Serial port if connected directly (eg. -c COM1) moteID [moteID…] List the Motes to download or check status.

Function Information Description:

Reprogram Service "BOOT" based on XServe provided by MoteWorks platform with communication port COM5.

Service Code: 1 05 1 61

1: MoteWorks PlatformID

05: Device: GatwayID (COM port=COM5)

1: Gateway Code of XServe

61: H_Repro_BOOT: Boot Service (VC Code)

Socket Port Code: 1 1 60

1: Platform Code or PlatformID: MoteWorks produced by Crossbow

1: Gateway Code of XServe

60: Reprogram Service (VCS Code)

1160: Socket Port

1160Req.xml: Reprogram Function XML file name

Note: the code rules and definitions refer to the Appendix A-C.

Demo:

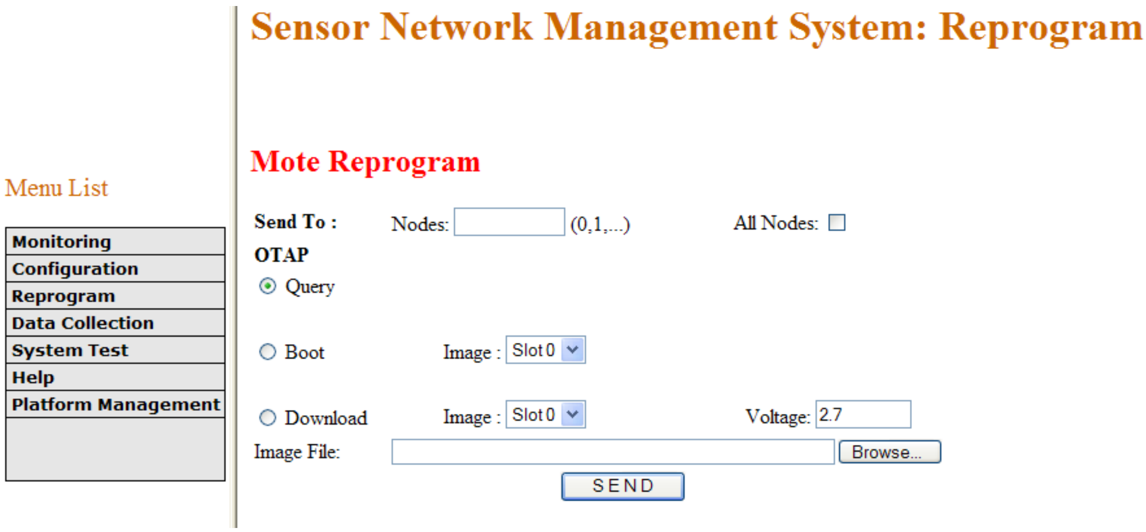


Figure 5.12 “Reprogram” UI

Options:

cmd = query
sf = localhost:9001
group id = 129
debug = 1
html report file = xotap.html
motes = 1458

Figure 5.13 Demo of “Query”

5.3.4. Data Collection Function and Demo

Figure 5.14 shows us the Logical Flow of WSN Data Collection Function.

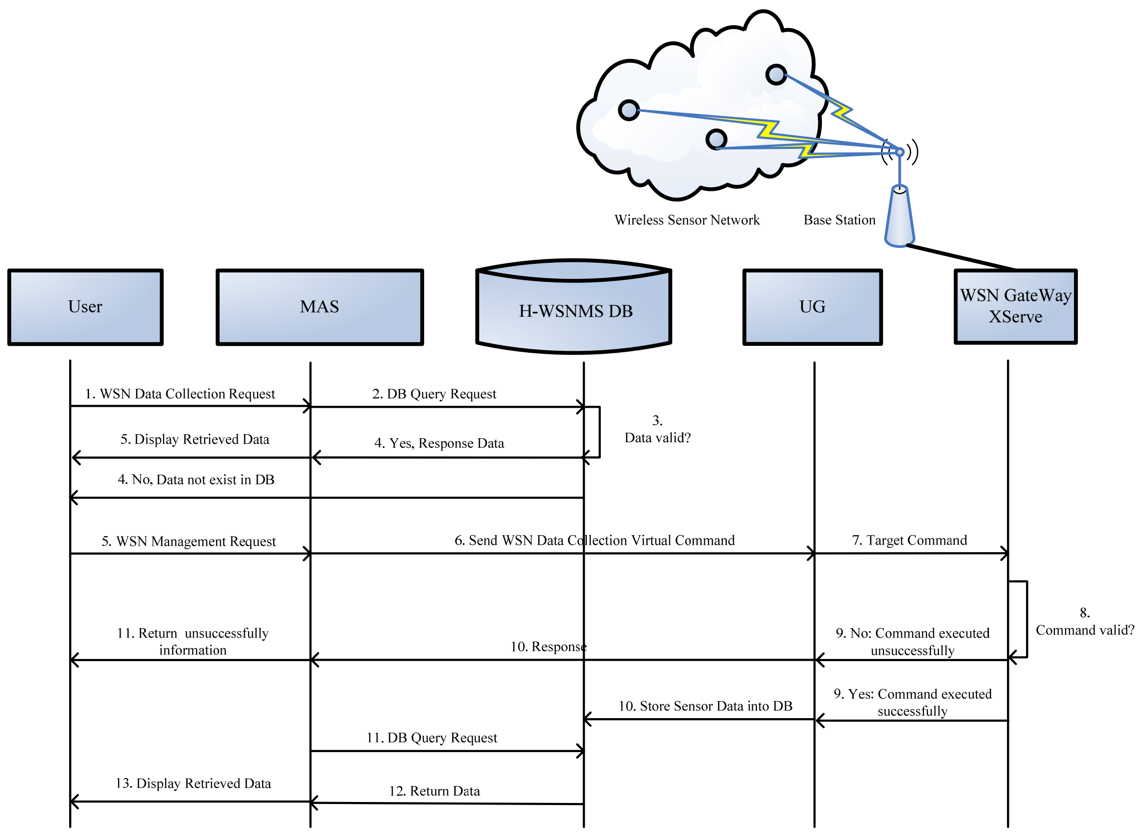


Figure 5.14 “Data Collection” Command Logical Flow

Function: user retrieves the wireless sensor data from H-WSNMS wireless sensor network data source in its own DB.

Flow Description:

Users send a WSN “Data Collection” request, system will visit the H-WSNMS DB to check whether the retrieved data existed or not, if yes, display the result to users, if no, user send a send a WSN “Data Collection” function request again, which will be wrapped to the virtual command XML package, then is interpreted and mapped to the target command string sent to XServe, then

XServe judges whether the target command string is valid or not; If not, return the information about unavailable data to users, if yes, the data coming from motes in WSNs synchronizes into H-WSNMS DB, then response and display the data to users according to users' query time requirement, i.e. Under the satisfaction of condition, the new data will be stored into DB; at the same time, return a "Data Notification". After receives the "Data Notification", the system will re-send DB query request. Thus, users retrieve the data with on-demand method.

Data Collection Request XML File and Mapped Result:

Table 5.5 Data Collection Request XML File and Mapped Command String

Function	Data Collection Request XML File
Request Node XML Format	<?xml version="1.0" encoding="UTF-8"?> < Datacollreq > <gateways> <gateway> <gatewayname>XServe</ gatewayname> <gatewayid>05</ gatewayid> <serviceID>105100</serviceID > <device>COM5</device > <interfaceboard> MIB520</interfaceboard> <baudrate >57600</baudrate > <dbinfor> <dbserver>149.166.32.252</dbserver> <dbport>5432</dbport> <dbname>IDAM</dbname> <dbuser>tele</dbuser> <dbpasswd>12345678</dbpasswd> <databaseparsed>l</databaseparsed> <xmlfile> XmlStream.xml</xmlfile> <xmlp></xmlp> <xmlport>9005</xmlport> </dbinfor> </gateway> <gateway> …… </gateway> </gateways> </Dataconnreq >
Mapped Target Command String	xserve –s=COM5 –b=57600 –dbserver=149.166.32.252 –dbport=5432 –dbname=IDAM –dbuser=tele -l –xmlfile=XmlStream.xml -xmlp –xmlport=9005
Note	**This is a General and Extendable file** **Example**: **Available Command parameters for XServer** (**Refer XServe Users Manual [7], in which there is the detail introduction about various XCommand Arguments**) main parameters: xserve -s -b -dbserver -dbport -dbname -dbuser -l -xmlfile -xmlp –xmlport

Function Information Description:

Data Collection Service based on XServe provided by MoteWorks platform with communication port COM5.

Service Code: 1 05 1 00

1: MoteWorks PlatformID

05: Device: GatwayID (COM port=COM5)

1: Gateway Code of XServe

00: H_DataColl: Data Collection (VC Code)

Socket Port Code: 1 1 00

1: Platform Code or PlatformID: MoteWorks produced by Crossbow

1: Gateway Code of XServe

00: Data Collection (VCS Code)

1100: Socket Port

1100Req.xml: Data Collection Function XML file name

Note: the code rules and definitions refer to the Appendix A-C.

Demo:

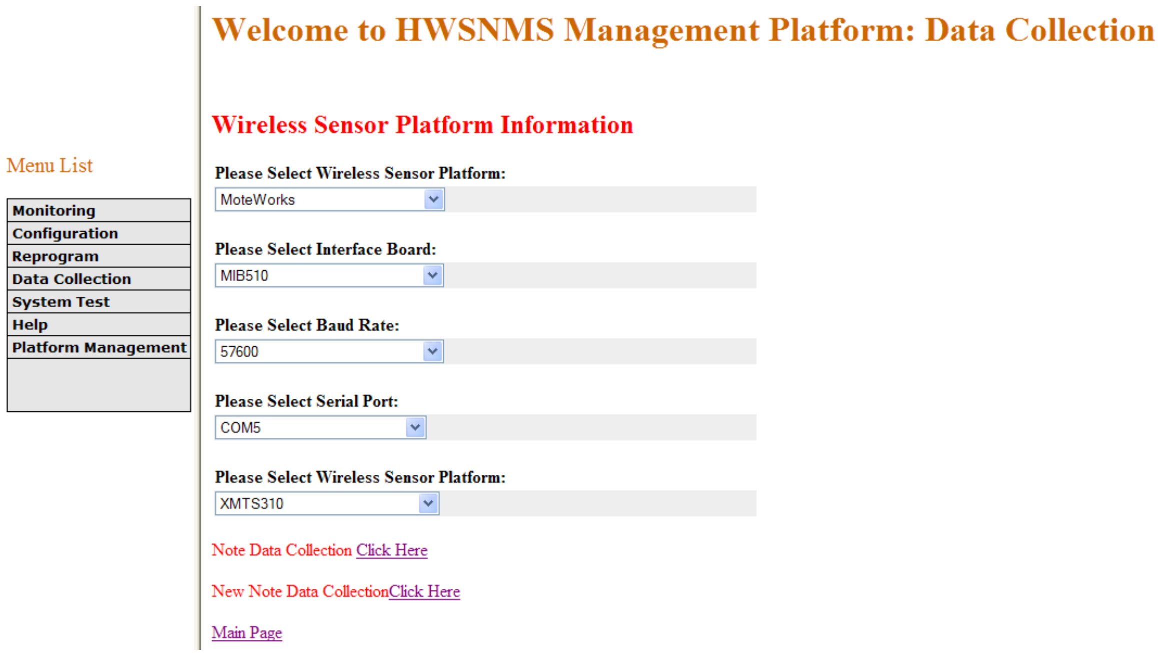
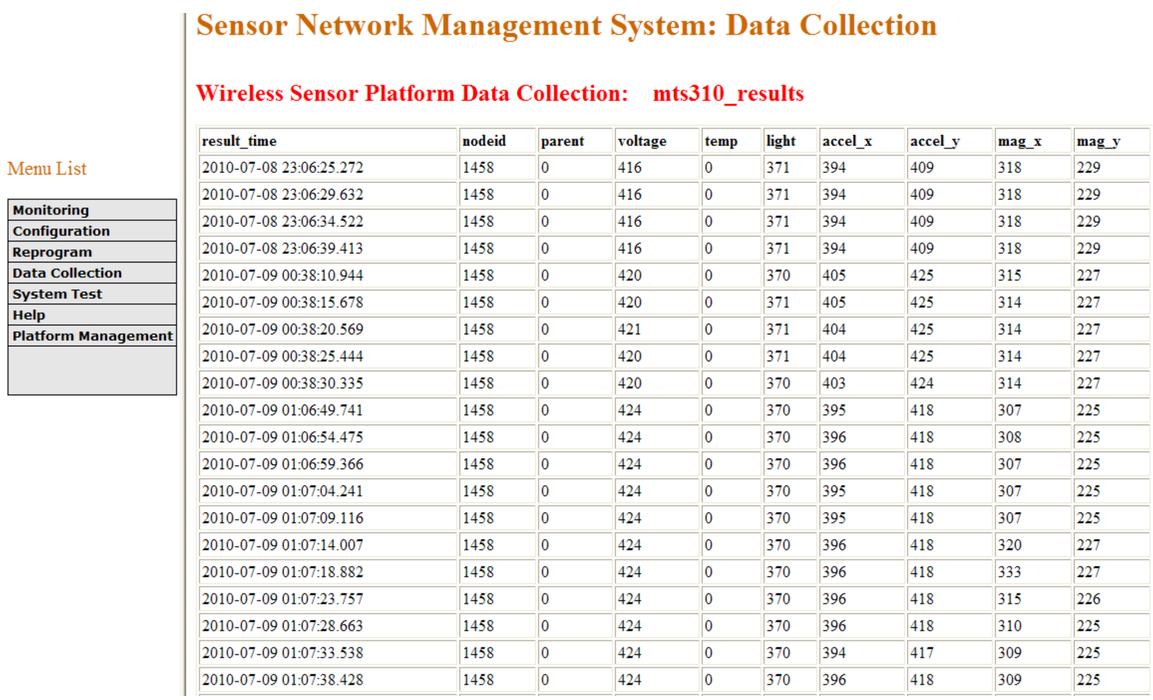


Figure 5.15 “Data Collection” UI



result_time	nodeid	parent	voltage	temp	light	accel_x	accel_y	mag_x	mag_y
2010-07-08 23:06:25.272	1458	0	416	0	371	394	409	318	229
2010-07-08 23:06:29.632	1458	0	416	0	371	394	409	318	229
2010-07-08 23:06:34.522	1458	0	416	0	371	394	409	318	229
2010-07-08 23:06:39.413	1458	0	416	0	371	394	409	318	229
2010-07-09 00:38:10.944	1458	0	420	0	370	405	425	315	227
2010-07-09 00:38:15.678	1458	0	420	0	371	405	425	314	227
2010-07-09 00:38:20.569	1458	0	421	0	371	404	425	314	227
2010-07-09 00:38:25.444	1458	0	420	0	371	404	425	314	227
2010-07-09 00:38:30.335	1458	0	420	0	370	403	424	314	227
2010-07-09 01:06:49.741	1458	0	424	0	370	395	418	307	225
2010-07-09 01:06:54.475	1458	0	424	0	370	396	418	308	225
2010-07-09 01:06:59.366	1458	0	424	0	370	396	418	307	225
2010-07-09 01:07:04.241	1458	0	424	0	370	395	418	307	225
2010-07-09 01:07:09.116	1458	0	424	0	370	395	418	307	225
2010-07-09 01:07:14.007	1458	0	424	0	370	396	418	320	227
2010-07-09 01:07:18.882	1458	0	424	0	370	396	418	333	227
2010-07-09 01:07:23.757	1458	0	424	0	370	396	418	315	226
2010-07-09 01:07:28.663	1458	0	424	0	370	396	418	310	225
2010-07-09 01:07:33.538	1458	0	424	0	370	394	417	309	225
2010-07-09 01:07:38.428	1458	0	424	0	370	396	418	309	225

Figure 5.16 Demo of “Data Collection”

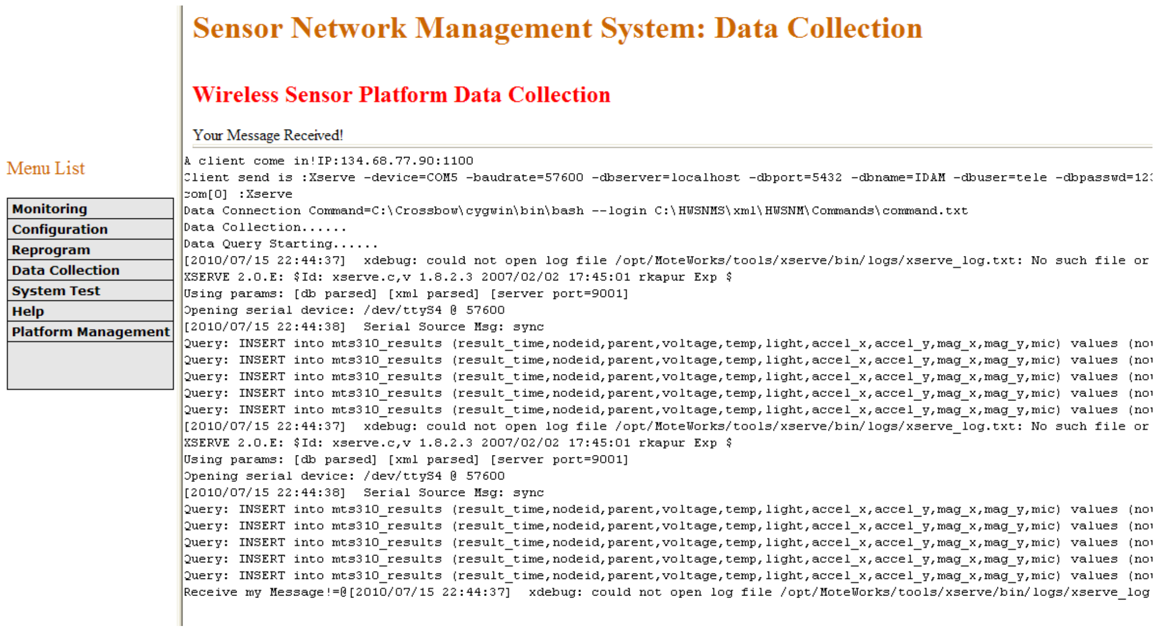


Figure 5.17 Demo of “New Data Collection”

5.4. XServe’s Extension

This section is not the very important part in the design and implement of H-WSNMS Architecture but worth mentioning, mainly considering the extension on some specific WSN gateway middlewares such as XServe for the future system developers, thus, H-WSNMS also can extend some new Virtual Command Sets it needs. The following is our extension based on XServe, which displays the flexibility and scalability of H-WSNMS.

In Figure 5.2, Three-tier architecture instantiation based on XServe, in which we put forward to an idea of extending the command library in XServe to improve the Configuration function , Considering no any source code, we would not extend the .dll file about XServe parameter command set. [2] proposes an extension method based on the XServe configuration existing available XCommand Set. XServe provides the only entry (i.e., port 9003 [7]) for XCommand inputs. After a mapped target command is wrapped in a packet and injected to wireless mesh network (XMesh), it will follow the flow shown in Figure 5.18, the command for configuring sampling rate will be finally executed and the acknowledge packet will be sent back to base station. In our application, except for periodic data collection on each mote, the following functions are needed from the client side with XCommand:

- Set Collection Rate: push sampled data to a queue structure and collect all sampled data at the end of each automatic collection period;
- Enforced Collection: send back all existing data samples in the queue.

These two configuration functions have been implemented through relocating the XCommand “SET_RATE” value field. In Figure 5.19, the highlight with red line shows us the demo of above extended configuration functions.

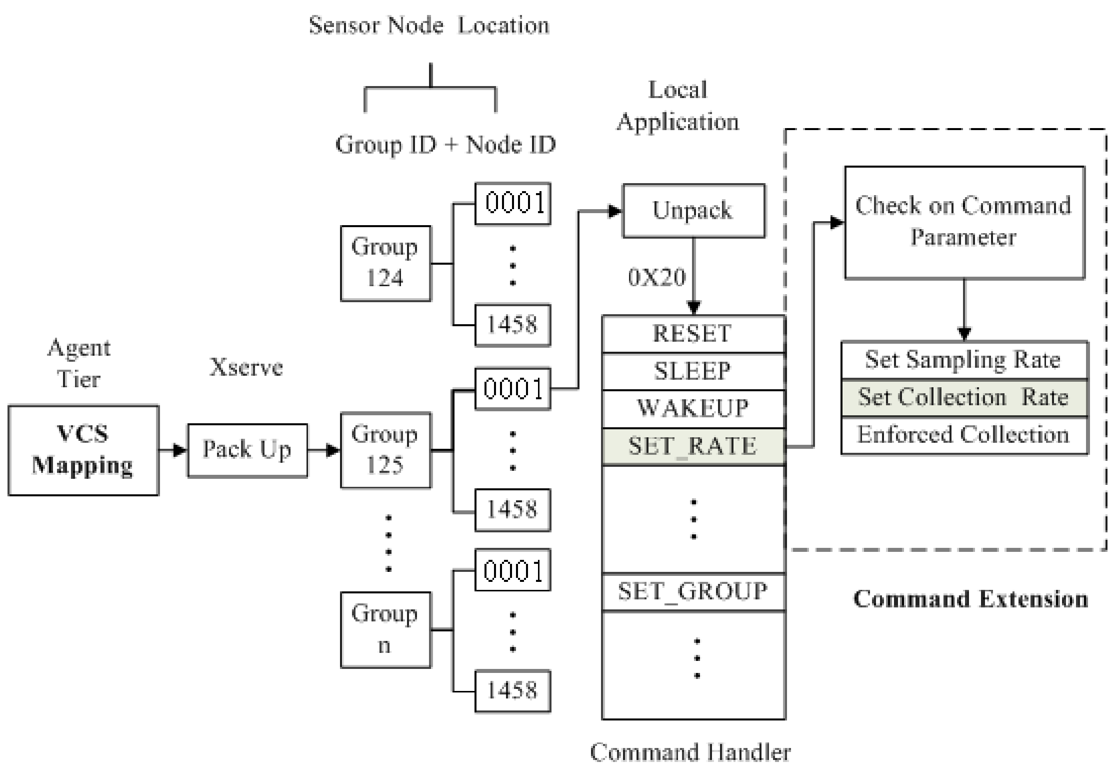


Figure 5.18 XServe Command Flow Illustration [2]

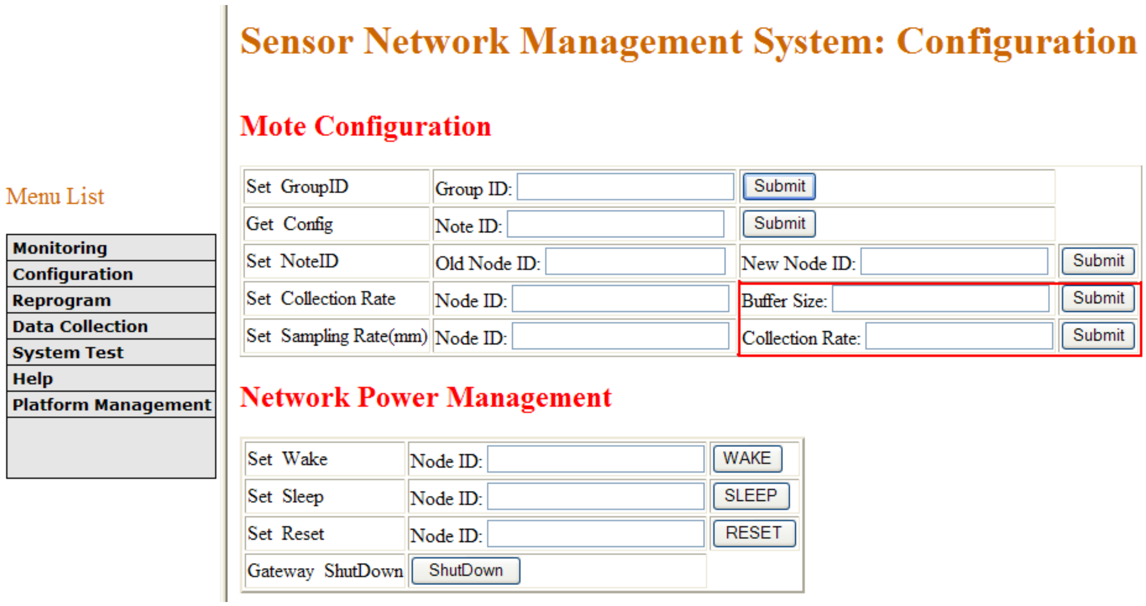


Figure 5.19 XServe Configuration Command Extension

CHAPTER 6. FUTURE WORK

We provide a scheme to manage sensor networks using XML schema, Database technologies and Socket Communication technology. The fundamental goal of the scheme is to be able to describe sensors in a simple, compact manner while still having the ability to represent essential details such as the general service functions (VCS), the type of sensor platforms that can be provided, the various parameters and application interfaces of specific gateway middlewares that are available in WSNs. Based on these technologies, we present a three layer framework H-WSNMS that provides the basic capabilities for locating, managing, and querying the heterogeneous Wireless Sensor Networks, at the same time; XServe command extension over existing command services has finished in this system. Consequently, the design and implementation of H-WSNMS is not only a challenge but also a chance for web-based heterogeneous Wireless Sensor Networks management system.

The underlying idea of H-WSNMS is to decouple the development of application-specific management functions from deployed heterogeneous WSN platforms and gateway technologies including their associated preliminary management command services. H-WSNMS architecture not only directly supports network management for heterogeneous WSNs, but also facilitates the reuse of each individual WSN's preliminary management tool as much as possible, and at the same time, presents to users a unified interface (UG) across multiple WSNs. We illustrated the H-WSNMS using XServe mote network through mapping H-WSNMS' Virtual Commands to both the existing XServe Command Service and the newly extended XServe Command Service to realize the flexibility and scalability of H-WSNMS. Our current H-WSNMS prototype is developed in Java. We plan to extend our prototype system to include two and more different WSN platforms and gateway technologies at the Mote layer to further study and verify our proposed new H-WSNMS architecture. We also plan to create more sophisticated management functionality at the MSA layer by the composition of a sequence of Virtual Commands.

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LIST OF REFERENCES

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APPENDICES

Appendix A.

Table A.1 Parameters Definition

Parameters	**Definition**
Platform Name	Wireless Sensor Platform Name Particle (produced by Particle Computer) µNode (produced by Ambient Systems) Sindrion (produced by Infineon Technologies) MoteWorks (produced by CrossBow)
Platform ID (*extendable*)	PlatformNo. N: 1~9
Gateway Name	e.g XServe
Gateway ID (*extendable*)	XX: 01~99
Gateway Code (*extendable*)	Y:1~9
Communication Port	COMx+1
Information send by users	Command Information from Users
ReqString XML	Stored in Service Repository Be used to describe the command service
ServiceID (*extendable*)	NXXY00~NXXY09 for H-DataColl VCS
	NXXY10~NXXY19 for H_Monitoring VCS
	NXXY20 for H_Config VCS NXXY21~NXXY39 for H_Config_Reconfig subVCS NXXY40~NXXY59 for H_Config_PM subVCS
	NXXY60~NXXY69 for H_Repro VCS
	NXXY70~ for H_Others VCS
VCS Category	H_DataColl Data Collection H_Monitoring Sernsor and gateway Information Monitoring
	H_Config Sernsor and gateway information configuration
	H_Repro Reprogram
SubVCS Category	H_Config: 1. H_Config_Reconfig 2. H_Config_PM
VCS Code	00: H_DataColl
	10: H_Monitoring
	20: H_Config
	60: H_Repro
	70: H_Others
ReqString XML (*extendable*)	1. Stored in Serviced Repository 2. Be parsed to Target Command String to send to Mote layer 3. XML file name based on Socket Port No. e.g: XML file for Data Collection NY00Req.xml
Socket IP	Socket Server IP address: xxx.xxx.xxx.xxx
Socket Port (PortID) (*extendable*)	NY00 for H_DataColl
	NY10 for H_Monitoring
	NY20 for H_Config
	NY60 for H_Repro

Table A.2 Command Category and Specification of VCS

VCS Category	VC	Command	Function
H_DataColl	H_DataColl		Data connection
H_Monitoring	H_Monitoring		Monitoring sensor data
H_Config	H_Config_Reconfig_SpRate	SET_RATE	Set new Sampling Rate
	H_ Config_Reconfig_NID	SET_NODEID	Assign Node ID
	H_ Config_Reconfig_GID	SET_GROUP	Assign a Node to new group
	H_ Config_Reconfig_CRate		Set collection rate
	H_Config_Reconfig_ECollect		Immediately perform a data collection from WSN and store it to DB
	……	……	……
	H_Config_PM_RESET	RESET	
	H_Config_PM_SLEEP	SLEEP	
	H_Config_PM_WAKEUP	WAKEUP	
	……	……	……
H_Repro	H_Repro_Boot		
	H_Repro_Query		
	H_Repro_Load		
	……		
H_Others	……	……	……

Appendix B.

Table B.1 XServe Command Line Parameters

<table>
<tr><th>XServe Command Line Parameters</th></tr>
<tr><td>Usage: xserve <-?|r|a|p|c|xr|xp|xc|dbxmlr|xmlp|xmlc|v|alert|m>
<-l=tablename>
<-dbserver=servername> <-dbport=portnum>
<-dbname=database name> <-dbuser=username>
<-dbpasswd=password>
<-h=path,hostname,portnum,config_file>
<-m=com,baud,protocol,slaveaddress,defaultregistervaluesas>
<-xmlfile=filename> <-xmlport=portnum>
[<-sf=hostname:port> | <-fsf=hostname:port> | <-device=dev>]
<-port=num> <-baud=num> <-platform=plt>
<-debug=level>
<-configfiles=filename:filename:>
<-loadparsers=filename:filename:...>
<-loaddatasinks=filename:filename:...>
<-heartbeat=<num missed>
-? = display help [help]
-r = raw display of tos packets [raw]
-a = ascii display of tos packets [ascii]
-p = parsed display of tos packets [parsed]
-c = converted display of tos packets [conveted]
-xr = raw tos packets xported to file [export raw]
-xp = parsed tos packets exported to file [export parsed]
-xc = converted tos packets exported to file [export converted]
-db = parsed tos packets exported to db [database parsed]
-dbserver = database server name (default=localhost)
-dbport = database server port number (default=5432)
-dbname = database name (default=MoteView db)
-dbuser = database user (default=MoteView user)
-dbpasswd = database user password (default=MoteView user password)
-l = parsed tos packets exported to db
(deprecated) [database parsed]
-xmlr = raw tos packets exported to xml [xml raw]
-xmlp = parsed tos packets exported to xml [xml parsed]
-xmlc = converted tos packets exported to xml [xml converted]
-xmlfile = file name to store exported xml (default=screen)
-xmlport = port number to start the xml server
-v = show version of all modules
-h = display data through web server
-m = export data using modbus
-port = set server port <default = 9001>
-sf = connect to unframed serial forwarder
-fsf = connect to framed serial forwarder
-device = connect to serial device <default = /dev/ttyS0>
-baud = set serial baud rate <default = 57600>
-platform = set platform. <default = mica2>
values=mica2dot|mica2|mica|telos|micaz
-debug = set debug level. <default = DBG_WARNING>
-alert = alert when data values are above/below specified ranges
-daemon = run in daemon mode</td></tr>
</table>

-nomonitor = run without a system monitor -configfiles = load xml configuration files. -loadparsers = load only the listed parsers files. (default=all files are loaded) -loaddatasinks = load only the listed datasinks files. (default=all files are loaded) -heartbeat = turn on the heartbeat monitor and reset after <num missed> -convZto2 = convert incoming network packets from micaZ headers to mica2 headers and vice versa -conv2toZ = convert incoming network packets from mica2 headers to micaZ headers and vice versa

Table B.2 XServe Configuration Command Line Parameters

<table>
<tr><th>XServe Configuration Command Line Parameters</th></tr>
<tr><td>Usage: xserve <-?|r|a|p|c|xr|xp|xc|dbxmlr|xmlp|xmlc|v|alert|m>
-device = connect to serial device <default = /dev/ttyS0>
-baud = set serial baud rate <default = 57600>
-device = connect to serial device <default = /dev/ttyS0></td></tr>
</table>

Table B.3 XServeTerm Line Parameters

<table>
<tr><th>XServeTerm Line Parameters</th></tr>
<tr><td>Usage: xcommand <-?> <-server=host:port> <-network=xmesh|xsensor>
-? = display help [help]
-server = xserve command port [host:port]
-network = network type (default = xmesh) [xmesh|xsensor]
-seq = starting sequence number (default=100)
-group = network group id (default=145)</td></tr>
</table>

Table B.4 XServeTerm Available Parameters

XServeTerm Available Parameters
Available Commands:
set_timeout <timeout ms>
set_starting_sequence <sequence number>
set_default_group <group id>
get_config <destination address>
set_rate <destination address> <new rate>
set_nodeid <destination address> <new node id>
set_groupid <destination address> <new group id>
set_rfchannel <destination address> <new rf channel>
set_rfpower <destination address> <new rfpower>
sleep <destination address>
wake <destination address>
reset <destination address>
xserve.shutdown
actuate <destination address> <device> <state>
device ids states
----
green led 0 off 0
yellow led 1 on 1
red led 2 toggle 2
all leds 3
sounder 4
relay1 5
relay2 6
relay3 7

Table B.5 XCommand Categories and Description

Command Category	Command	Arguments	Description
Power Management	RESET SLEEP WAKEUP		To reset the sleep and wakeup time.
Basic Update Rate	SET_RATE		To get or set the update rate. The set_rate command changes the data acquisition duty cycle of the mote. The first argument is the new timer interval in milliseconds.
Mote Configuration Parameter Settings	• GET_CONFIG • SET_NODEID • SET_GROUP • SET_RF_POWER • SET_RF_CHANNEL		This set of commands allows you to get and set radio frequency and power, including channel.
Actuation	ACTUATE • SET_LED • SET_SOUND • SET_RELAY	0=OFF, 1=ON, 2=TOGGLE 0=OFF, 1=ON 0=OFF, 1=ON	This set of commands actuates each individual LED with the option to operate on all three LEDs. This command turns the sounder off or on. This command turns the relays on

Table B.6 XServe Reprogram Line Parameters

<table>
<tr><th>XServe Reprogram Line Parameters</th></tr>
<tr><td>Usage: xserve <-?|r|a|p|c|xr|xp|xc|dbxmlr|xmlp|xmlc|v|alert|m>
-? = display help [help]
-p = parsed display of tos packets [parsed]
-c = converted display of tos packets [conveted]
-v = show version of all modules
-port = set server port <default = 9001>
-sf = connect to unframed serial forwarder
-fsf = connect to framed serial forwarder
-device = connect to serial device <default = /dev/ttyS0>
-baud = set serial baud rate <default = 57600>
-platform = set platform. <default = mica2>
values=mica2dot|mica2|mica|telos|micaz</td></tr>
</table>

Table B.7 XOtap Command Arguments

Command Interface	Description
-f <image_file>	Download the file
-i <image_number>	Image number
-q	Query the Mote status
-v <threshold>	Download if the voltage is above the threshold (default 2.7v)
-p <image_number>	Boot the image number
-sf <ip:port>	XServe host/port (default to localhost:9001)
-c <COM port>	Serial port if connected directly (eg. -c COM1)
moteID [moteID…]	List the Motes to download or check status

Note: The above parameters referring the XServe Manual and Mesh Manual provided by CrossBow MoteWorks.

Appendix C.

Table C.1 Monitoring ServiceID Definition

H_Monitoring VCS (NXXY10: *extendable*)	
ServiceID	**Description**
105110	H_Monitoring: Monitoring WSN xserve –s=COM5 –b=57600
……	……

Table C.2 Configuration ServiceID Definition

H_Config_ReConfig VCS (NXXY20~ NXXY39: *extendable*)	
ServiceID	**Description**
105121	H_ Config_Reconfig_GID set_default_group <group id>
105122	H_ Config_Reconfig_GetID get_config <destination address>
105123	H_ Config_Reconfig_SetNID set_nodeid <destination address> <new node id>
105124	H_ Config_Reconfig_SpRate set_rate <destination address> <new rate>
105125	H_ Config_Reconfig_CRate set_collection_rate <destination address> <new size>
105126	H_ Config_Reconfig_ECollect set_manual_collection <destination address> <Flag>
……	……
H_Config_PM VCS (NXXY40~ NXXY59: *extendable*)	
ServiceID	**Description**
105140	H_Config_PM_WAKEUP wake <destination address>
105141	H_Config_PM_SLEEP sleep <destination address>
105142	H_Config_PM_RESET reset <destination address>
105143	H_Config_PM_SHUTDOWN xserve.shutdown
……	……

Table C.3 Reprogram ServiceID Definition

H_Repro VCS (NXXY60~69: *extendable*)	
ServiceID	**Description**
105161	H_Repro_BOOT C:/Crossbow/cygwin/opt/MoteWorks/tools/xotap/bin.cygwin.x86/;xotap.exe –I 2 -p -v 2.7 -sf localhost:9001 1458
105162	H_Repro_QUERY C:/Crossbow/cygwin/opt/MoteWorks/tools/xotap/bin.cygwin.x86/;xotap.exe –I 2 -q -v 2.7 -sf localhost:9001 1458
105163	H_Repro_LOAD C:/Crossbow/cygwin/opt/MoteWorks/tools/xotap/bin.cygwin.x86/;xotap.exe –I 2 -f C:/main.exe.ihex -v 2.7 -sf localhost:9001 1458
……	……

Table C.4 Data Collection ServiceID Definition

H_DataColl VCS (NXXY00: *extendable*)	
ServiceID	**Description**
105100	H_DataColl xserve –s=COM5 –b=57600 –dbserver=149.166.32.252 –dbport=5432 –dbname=HWSNMS –dbuser=tele -l –xmlfile=XmlStream.xml -xmlp –xmlport=9005
……	……

Note: The above definitions referring the parameters provided by XServe in MoteWorks platform.

Appendix D.

Table D.1 DataTable H-WSNMS_ServicInfor

Parameter name	Type	Size	Key	Default Value	Statement
ServiceID	nVarChar		Yes		PlatformID+gatewayID+gatewaycode+ VCcode
PlatformName	nVarChar				e.g MoteWorks
PlatformID	nVarChar				Unique indentified number for Wireless Sensor Platform
gatewayName	nVarChar				e.g XServe
gatewayID	VarChar				X0 X:1~9
gatewayCode	VarChar				Type number of gateway e.g XServe=1
ServiceCategory	nVarChar				Classified into monitoring, configuration, reprogramming and so on e..g H_DataConn H_Config H_Repro
CategoryFirstNum	nVarChar				00 for H_DataConn 10 for H_Monitoring 20 for H_Config 60 for H_Repro
ServiceCode	nVarChar				Category number of ServiceID
XMLfileName	nVarChar				XML file Name
SocketPort	nVarChar				Socket Port
Reserved1	nVarChar			Null	
Reserved2	nVarChar			Null	

Table D.2 Datatable H-WSNMS_PlatformState

Parameter name	Type	Size	Key	Default Value	Statement
PlatformName	nVarChar		Yes		Wireless Sensor Platform
PlatformID	nVarChar				Unique indentified number for Wireless Sensor Platform
GatewayName	nVarChar				Gateway Name e.g XServe
GatewayID	nVarChar				COM port number
PlatformState	nVarChar				0: set up 1: shut down
Reserved1	nVarChar			Null	
Reserved2	nVarChar			Null	

Table D.3 Datatable H-WSNMS_SocketInfor

Parameter name	Type	Size	Key	Default Value	Statement
ServiceID	nVarChar		Yes		PlatformID+gatewayID+gateway code+ VCcode
ServiceCategory	nVarChar				Classified into monitoring, configuration, reprogramming and so on e..g H_DataConn H_Config H_Repro
CategoryFirstNum	nVarChar				00 for H_DataConn 10 for H_Monitoring 20 for H_Config 60 for H_Repro
SocektIP	nVarChar				xxx.xxx.xxx
SocektPort	nVarChar				Socket port number
Reserved1	nVarChar			Null	
Reserved2	nVarChar			Null	

Table D.4 Datatable H-WSNMS_GatewayConfig

Parameter name	Type	Size	Key	Default Value	Statement
ServiceID	nVarChar		Yes		PlatformID+gatewayID+gatewaycod e+ VCcode
PlatformName	nVarChar				Wireless Sensor Platform
PlatformID	nVarChar				Unique indentified number for Wireless Sensor Platform
OSplatform	nVarChar				Operation System
EfilePath					Executable file Path
Efile	nVarChar				Executable file e.g XServe.exe XServeterm.exe XToap.exe
Reserved1	nVarChar			Null	
Reserved2	nVarChar			Null	

Appendix E.

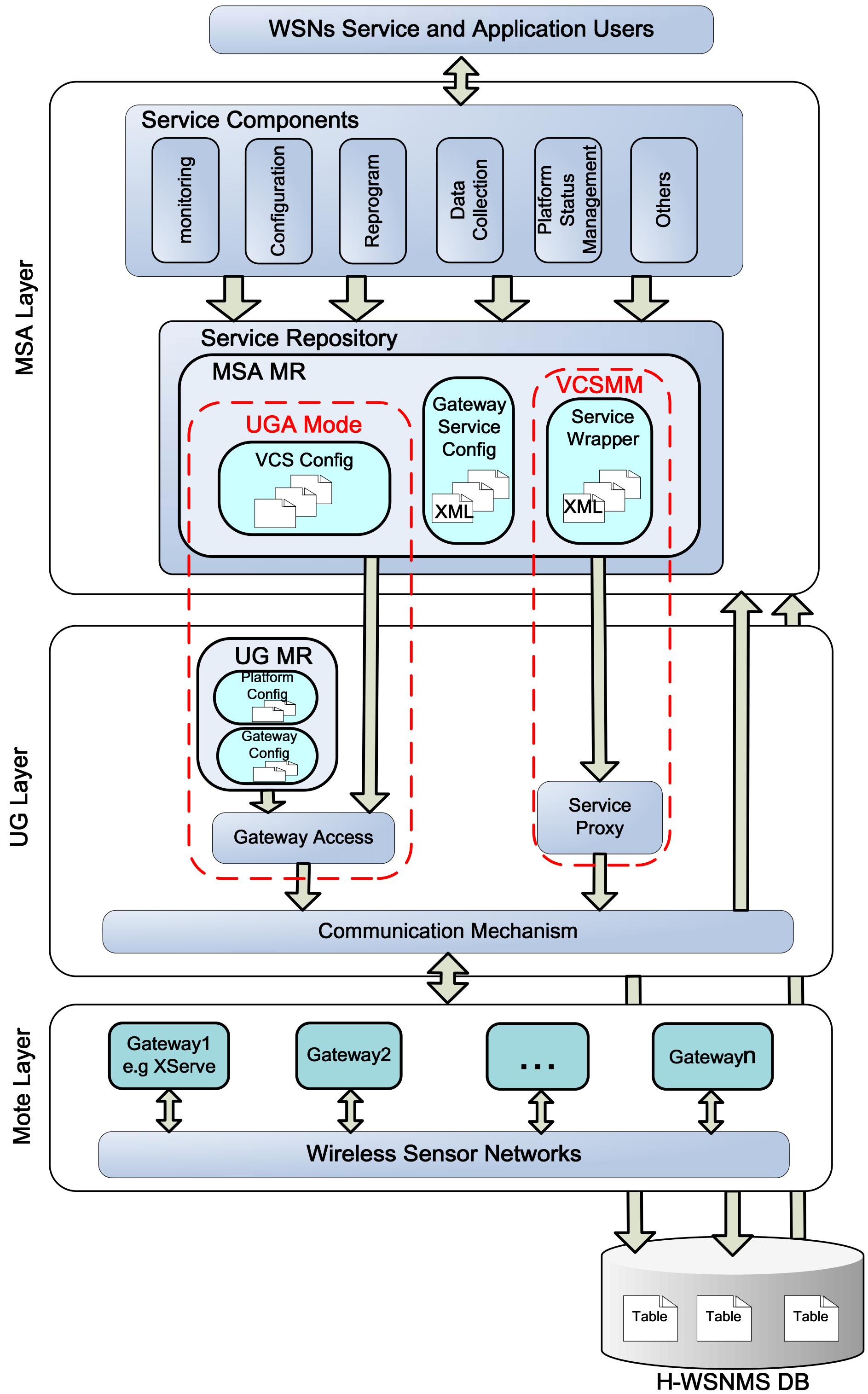

Figure E.1 the Whole Design of H-WSNMS