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Novel Design of Inland Shipping Management Information System Based on WSN and Internet-of-things

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ABSTRACT: Currently there are more and more ships sailing in inland waterways so that the traditional inland shipping management information system (ISMIS) becomes relatively backward. Based on the rapidly developed new information technologies, such as wireless sensor network, Internet-of-things, cloud-computing and so on, we propose a novel design of ISMIS, which is featured by low cost, environment-friendly, cross platform, high scalability and integrity and thus can efficiently improve the inland shipping management and inland water environment.

1 INTRODUCTION

Wireless sensor networks (WSN) have attracted considerable amount of attention in recent years. There is a sort of sensors in WSN, including seismic sensors, temperature sensors, and humidity sensors etc. It is a new way of acquiring information platform that can supervise and collect various monitor objects' state. Its sensors can be positioned to many geographical areas that human being can hardly arrive even can't approach, for instance, volcano, the arctic pole and hostile battle fields and so on. Small size and minimum requirements from existing infrastructure make WSN one of revolutionary technologies in 21st century that will have a significant impact on our future life.

On the other hand, internet-of-things (IOT) is designed as a world-wide network in which everything can be identified by a unique address, every computer, each desk so much so that even a stone can acquire an exclusive address if we need. Every object can join the network dynamically and each terminal can collaborate and cooperate efficiently to achieve different tasks. IOT can realize real-time data obtaining, information exchange, remote control making use of traditional internet. IOT finds a range of applications in daily life including intelligent transportation system, smart home furniture, intelligent fireproof and so on.

Nowadays vessels sailing in inland waterways are increasing dramatically while the existing inland navigation management information system cannot provide more efficient service for inland rivers' management. Shortages of the management system have manifested themselves in following spheres. Firstly, fewer applications of advanced techniques are employed in inland shipping administration. According to the survey statistics, ship-borne supervising devices are mostly deployed in ocean transportation vessels, namely AIS, GPS, RADAR, and other modern technologies are scarcely mounted in inland ships. Secondly, time-delay in current monitoring system is larger, in other words information or data broadcasted by the system are not latest. What's more it is difficult for such system to realize supervise and exchange information across the areas. As a result more efficient real-time shipping management system and more convenient data information sharing system are required. Development of WSNs and IOT make it possible to implement the very watercraft management system. The newly system can achieve low latency, inter-regional organizing network, easy realization and other advantages with the help of WSN and IOT for the aforementioned superiorities are the unique properties of these burgeoning IT technologies.

The remainder of the paper is organized as follows: In section 2 we present related work. In section 3, we propose whole design of inland shipping management system, including introduction of system functionality, design of network structure. Meanwhile system's data processing based on cloud computing is discussed in section 4 and middleware system of inland shipping management system is expounded in section 5. Then the paper is concluded in section 6.

2 RELATED WORK

I.F. Akyildiz et al. [1] provided a review of factors influencing the design of sensor networks and the communication architecture for sensor networks was outlined. In addition the algorithms, protocols for each layer and open research issues for the realization of sensor networks were also explored. He gives us a better understanding of applications of sensor network and the current research issues in the field, like node localization, designing energy efficient radio circuits, sensor network topology, fulfillment of its adaptivity to environment, protocols for sensor network's different layers and so on. It will be better if the authors talk about difference between traditional sensor networks, wireless sensor network as former can provide some assistance for the later.

The machine learning techniques applied in WSN from both networking and application perspectives were surveyed by Ma Di et al. [2]. Machine learning techniques have been applied in solving problems such as energy-aware communication, optimal sensor deployment and localization, resource allocation and ask scheduling in WSNs. In application domain, machine earning methods are mainly used in information processing such as data conditioning, machine inference and etc. The paper proposes a novel approach that first extends rigorously published mathematical constructs that merely approximate the long-term or stationary behavior of information flows in WSNs to simplify computation and simulation. Moreover, the approach, based on multivariate point processes, is shown to represent interaction of the parameters of the protocol layers by William S. Hortos [3]. Both Ma Di [2] and William S. Hortos [3] are talking about machine learning techniques while Ma focuses on the application aspects and William mainly on theoretic field, and their conclusions may be more stringency if they present some simulations.

When deploying several applications over the same WSN, One of the remaining problems resides in the data aggregation solutions, which are proposed generally for one application and may drain the WSN power in a multi-application context. Therefore, Ahmad Sardouk et al. [4] propose a data aggregation scheme based on a multi-agent system to aggregate the WSN information in an energy-efficient manner even if we are deploying several applications over this network. This proposal has proved its performance in the context of one and several applications through successive simulations in different network scales. Ahmad Sardouk gives us a concrete data priority processing scheme, and it would be better if it provides some mathematical model for the data aggregation scheme and discusses the scheme's node localization.

As ZigBee becomes a standard for WSN (Wireless Sensors Networks), and ZigBee and 802.15.4 had been proving they can achieve the mission splendid, Xavier Carcelle et al. [5] will emphasize on the past, present and future features for ZigBee, taking a look on the feedback from previous implementations to finally design the next generations of WSN based on ZigBee. Xavier Carcelle introduces the past, present and future features for ZigBee in detail, taking a look on the feedback from previous implementations to finally design the next generations of WSN applications based on ZigBee. If he connects WSN s' applications with some new developing techniques, such as internet-of-things, cloud computing and so forth, it will be perfect.

The research presented by Fuxing Yang et al. [6] has been focused on wireless gateway based on ZigBee and TD network. According to problems caused by limited bandwidth of traditional wireless sensory gateway, such as inferior network performance and low efficiency of communication, this paper comes up with a solution---a wireless sensory gateway based on ZigBee/TD, closely combining ZigBee net with TD-SCDMA net. In the plan of design, the network nodes transport data to gateway by ZigBee short-range communication technique after collecting them and the gateway sends them to control center by TD network from long distance, realizing the highly efficient long-range transport of data. The design satisfies the efficiency and transparency needed for inter-networks data exchange and it can be scalable easily. Fuxing Yang gives an excellent wireless gateway scheme and it may be more persuasive supposing that Fuxing Yang introduces some related work.

Miaomiao Wang et al.[7] provide a comprehensive review of the existing works on WSN middleware, seeking for a better understanding of the current issues and future directions in this field. They also propose a reference framework to analyze the functionalities of WSN middleware in terms of the system abstractions and the services provided and review the approaches and techniques for implementing the services. Based on the analysis and using a feature tree, the paper provides taxonomy of the features of WSN middleware and their relationships, and uses the taxonomy to classify and evaluate existing works. Open problems in this important area of research are also discussed in [7]. Miaomiao Wang gives us an overall detailed existing research on WSN middleware. The paper can be a more cogency survey as if he tells some transport protocols in WSN middleware.

Study on Internet-of-things is either in full swing. Jianhua Liu et al. [8] propose a formal IOT context model to perform self-adaptive dynamic service. They provide a general context aware service based on IOT communication and their context model is used for service match and service composition to reduce the consumption of devices resources and cost. Stephan Haller et al. [9] survey that how the Internet of Things is put in a wider context: how it relates to the Future Internet overall and where the business value lies so that it will become interesting for enterprises to invest in it. Stephan Haller also proposes the major application domains where the Internet of Things will play an important role and potential concrete business opportunities. Aitor Gomez-Goiri et al. [10] address the progress towards a semantic middleware which allows the communication between a wide range of embedded devices in a distributed, decoupled, and very expressive manner. This solution has been tested in a stereotypical deployment scenario showing the promising potential of this approach for local environments. Welbourne E. et al. [11] design a suite of Web-based, user-level tools and applications to empower users by facilitating their understanding, management, and control of personal Radio Frequency Identification (RFID) data and privacy settings. These applications are deployed in the RFID Ecosystem and a four-week user study is conducted to measure trends in adoption and utilization of the tools and applications as well as users' qualitative reactions.

Jianhua Liu [8] provides a simple enhanced dynamic service selection model and a formal internet-of-things (IOT) context model; both of the models are self-adaptive dynamic service model, and it would be better as if the paper provides some mathematical models. Stephan Haller et al. ([9]-[11]) tell us something more about IOT's concrete enterprises applications, combined with its specific applying techniques, such as RFID, middleware and so on. From personal point of view, the three papers need some simulations. Stephan Haller [9] need to supplement some content in chapter of the major technique issues, such as privacy, virtual and physical world fusion and so on, as these are important for the spread of IOT in future. Aitor Gomez-Goiri et al. [10] can introduce something concerned with IOT middleware and distributed computing so that the paper may be more consummate. Analogously, Welbourne E. [11] may replenish some information about RFID middleware for building the internet-of-things era.

3 INLAND SHIPPING MANAGEMNET INFORMATION SYSTEM

3.1 *System functionality*

Currently inland shipping management is in comparatively chaotic state. Vessel control and supervise departments are distributed in different regions such that management efficiency is lower for information barrier and information island. Evolution of IOT and WSN provides novel approach for internal navigation administration. Accordingly it is high time to establish a more efficient integrated management information system, which we refer to as Inland Shipping Management Information System (ISMIS) catering to the aforementioned claim.

ISMIS takes advantage of wireless sensor network technology, RFID technique, and IOT to provide real-time information for inland ships, vessel management department, and other correlative administrative departments. RFID tags embedded in ship can transform ships' dynamic and static information to base station, auxiliary sensors can deployed in inland waterways, bridges, ships which haven't been equipped with RFID equipments or other identification facilities and other places if necessary. Wireless Sensor Networks can acquire and survey ships' state (including ship's name, vessel's number, tonnage of ship, vessel course, and navigational speed etc.) accurately such that upper computers and central control monitoring system can raise the management level tremendously.

WSN that used to detect environment and device status can avoid some unwanted accidents. For instance, sensors deployed in bridge will detect bridge's intensity of pier and bridge girder by the minute so that its hidden danger can be hustled out of the way as early as possible. Sensors in ISMIS can also aid navigation as they can broadcast fairway information ahead such as traffic condition, traffic density, navigational danger, water area state, and so forth.

What's more ISMIS provides a good basis for the standard of RFID technique, information system, information encoding, measurement, management mode, manipulation, and other technique touchstone.

3.2 *Design of network framework*

Network structure of ISMIS includes wireless sensor networks, cable network, terminal users and, management system server, and so forth. Cable network mainly presides over the communication among terminal customers, principal computers, and center controlling system. Data transmitted from base station or principal computers can be sent to center controlling system by cable network. Users' requests and administrators' management activities are executed through internet. Spot data and information delivered by RFID data acquisition unit can be gained by upper computers in real-time. The architecture of network frame is displayed in Fig. 1.

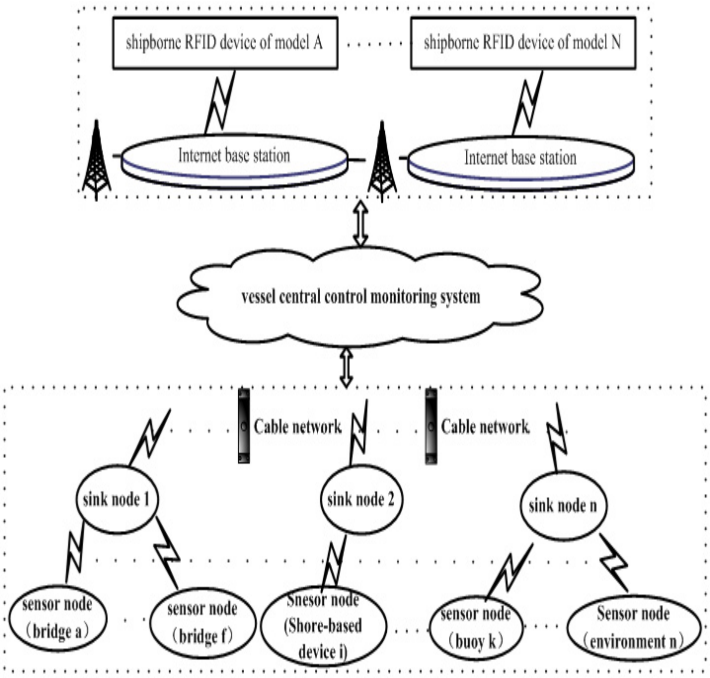

Figure 1. Architechture of network framework

Wireless sensor network in ISMIS primary implements function of detecting vessel information, environment state, bridge information, traffic status, and other factors which affect vessel operation. Sensor nodes can be divided into four categories: vessel nodes, bridge nodes, shore-based nodes, underwater nodes, and other nodes. With nodes distributed in a variety of monitoring areas, we can coverage most of supervising areas at the cost of lower costing such that all monitoring targets will transfer their status messages, at regular time, to base station or other data acquisition devices. WSN is ambient environment self-adaptively ad hoc network; it consists of physical layer, MAC layer, topology layer, network layer, transfer layer, and application layer. On one hand, RFID data collecting facilities sweep ship-borne RFID device to get watercraft's relative information at a fixed time, and data acquired in real-time are transmitted to local vessel management department and vessel center control monitoring system by RFID middleware system. On the other hand, vessel sensor nodes, which have been equipped with microchips that can realize information exchange automatically, underwater sensor nodes, shore-based nodes, and other sensor nodes shape ad hoc network. The ad hoc network is able to get and deliver supervising range's dynamic information and static state in real time which enhance remote management efficiency. Certainly WSN's information and data should be transferred to center management monitoring system with the help of WSN information middleware system. Partial pseudo-codes of WSN information middleware system are as follows:

```
Implementation {components vessel-node;
Class create-node-information
{Public:
Transfer (vessel-node information);
Private:
Char* vessel-node location;
Char* vessel-speed;
Char* vessel-direction;
int vessel-call-sign;
int vessel-IMO;
};
Refresh information database;
Return 0 ;}
```

3.3 *Design of inland shipping management information system*

Inland shipping management information system (ISMIS) employs wireless sensor network, RFID technique, IOT technology and other modern IT technique into inland vessel administration. ISMIS realizes precisely control over inland ships by the aid of WSN, IOT, and RFID, for the center control and management system of ISMIS can receive supervisory scope information concerning ships, navigation lock, fairway, traffic density, and other correlative data.

WSN in ISMIS plays the role of monitoring most targets, such as ships sailing in inland rivers, buoys, environment state, navigation danger, and so forth. WSN combines with RFID constitutes ISMIS bracket and network nerve. With the help of such modern IT technique, ISMIS can effectively schedule distributed vessel management subsystem and ship sailing in inland rivers so as to prevent traffic jam and accidents happening. Structure of ISMIS is showed in Fig. 2.

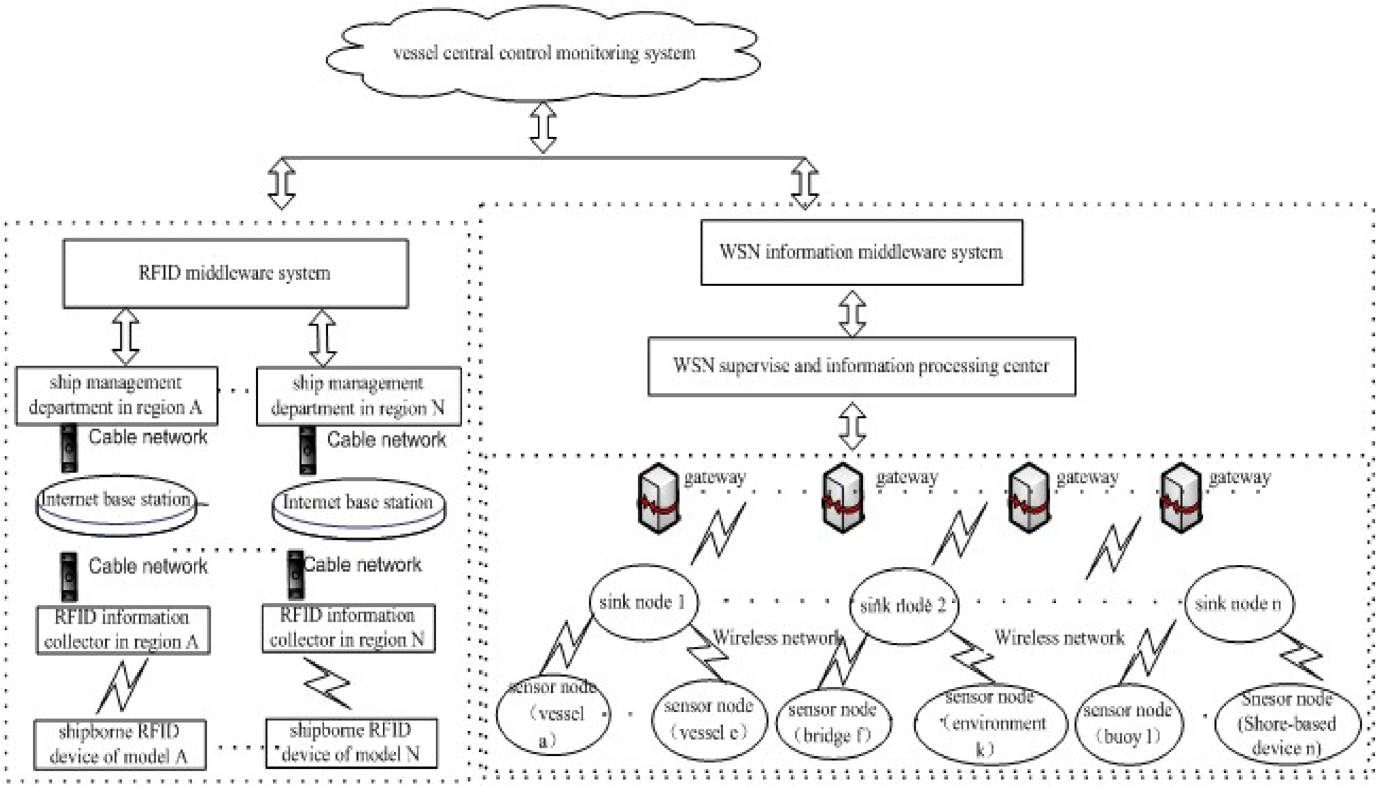

Figure 2. Architecture of inland shipping management information system

3.4 *Achievement of dynamic node connecting to local cluster network*

As vessels are shipping on inland rivers, nodes of WSN are changing constantly. Therefore locomotive ship nodes connect to local WSNs via wireless sensor networks gateway and concrete realization as follows:

Step 1: apply for joining native sub-WSN

A ship which functions as traveling node need to join native wireless sensor sub-network to formulate real time ad-hoc network. First thing for the mobile node is applying for registration in the sub-network. It broadcasts gateway request messages over the sub-network. The nearest sink node of the sub-network will build request-join node's path distance variable-Hops as soon as it receives registration messages delivered by ship node, and its initial value is 0. Then sink node sends permission messages of joining sub-network and application affirm information to the application node by cluster's nodes. That very node will deliver response verification messages to sink node such that sink node can dynamic updates cluster nodes information.

Step 2: registration in the sub-network

Ship node transmits its relevant information, involving path hops, routing information and other information to sink node to login the cluster as a temporary member. Head-node forwards the receiving information to upper-computer system through wireless gateway. Upper- computer system generates provisional ID for new ship node and stores its information into ship node database. After that, extemporaneous ship node ID, registration identifying code and other essential data packets are sent to sink node and vessel sensor. Ship node can complete registering procedure so long as it receives extemporaneous ID and registration code. So far, sink node possess newcomer's information while it obtains upper-computer system's consent orders, such as registration node ID, registration area and so forth. Till then it is legal for the newcomer communicates with sink node and executes the task assigned by super-stratum node. The representation of the node joining local sub wireless sensor network is displayed in Fig. 3.

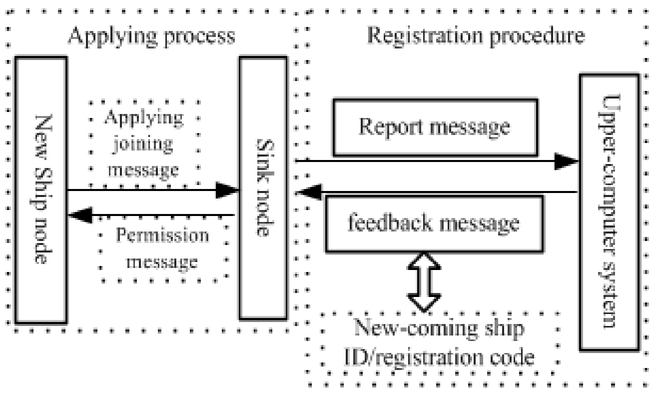

Figure 3. Schematic of new node joining into native sub-wsn

Step 3: task process

On the one hand, the new-coming member node needs to coordinate with sink node, shore-based nodes, environment supervising nodes and other nodes to realize information sharing that supervised and transmitted by upper nodes.

Ship-borne information collecting device, namely ship node transfers its data and acquired information to sink node which will transmit them to local vessel management department after data filtering and screening by network base station. Simultaneously, native environment nodes and bridge nodes and other relative nodes broadcast their monitoring data and messages to vessel controlling center which comprise of traffic density, water quality, embargo announcement, fair-way condition ahead and so on to shipping management centre to realize maximum efficiency of the whole wireless sensor network. In addition each sink node and nodes in every cluster communicate with each other through optimal path, while gateway link sensors are deployed in every navigation bridge, distributed to implement remote control and converting protocols between different networks and sink nodes.

4 DATA PROCESSING BASED ON CLOUD COMPUTING

Currently there is no uniform international definition of cloud computing. Domestic IT industry gives the definition of cloud computing as follows: cloud computing is the fusion of the traditional IT technologies and some newly developing techniques; the former involves grid computing, distributed computing, parallel computing, utility calculation, network storage, virtualization, load balance and the latter mainly comprises grid technology.

Inland shipping management information system as a large-scale inland crafts management system, it will handle, transmit, and store mass data as well as huge quantity of information and it really a challenge for we to implement sufficient facilities to accomplish such function. However cloud computing can meet our demand in acceptable overhead. For this reason we make use of could computing to conduct, store and broadcast our data as same as information.

The specific procedures as follows: firstly, data or messages delivered by RFID middleware systems are decrypted, filtered, transformed in the light of stated format and requirement by distributed calculating center, which includes virtual computing centers and physical calculating centers, in cloud computing platform. Then vessel central control monitoring system which is the command center of inland shipping management information system will publish warning information for ships if any obstructions exist in front of the waterway. In addition, cloud computing can also forward, convert format of correlative upper computers' orders for rock-bottom devices and equipments. Besides, WSN middleware systems dispatch their gathering information to vessel center monitoring system through wireless transmission protocol and then all messages are conducted by cloud computing which as with processing RFID devices' information.

5 MIDDLEWARE SYSTEMS DEVELOPMENT

In the inland shipping management information system middleware systems are essential for the data and information of ship-borne RFID devices and WSN nodes are incompatible in upper computer systems. Consequently we need to develop RFID middleware system and WSN middleware system respectively. Function modules of RFID middleware system comprise formatting data, ensuring data communication security, data caching and filtering module, supplying application program interfaces etc [12]. That's to say, all data and messages delivered by ship-borne facilities will be processed before they are sent to vessel central control monitoring system. To the contrary, all messages would be transformed to compatible formats before they are transmitted to lower layer or bottom users broadcasted by ship central control supervisory system.

WSN middleware system is somewhat resembling RFID middleware system. The middleware system offers several terminal users' interfaces for outside applications, including ship node middleware interface, bridge node middleware interface, water-supervisory node middleware interface, and other comprehensive interfaces for different kind of sensor nodes. These interfaces will transmit and receive data or information as required in WSN processing and monitoring center. Internal function modules of WSN middleware will execute their regular work automatically as long as relative data or information access into database of middleware system. The architecture of WSN middleware system is shown is Fig. 4.

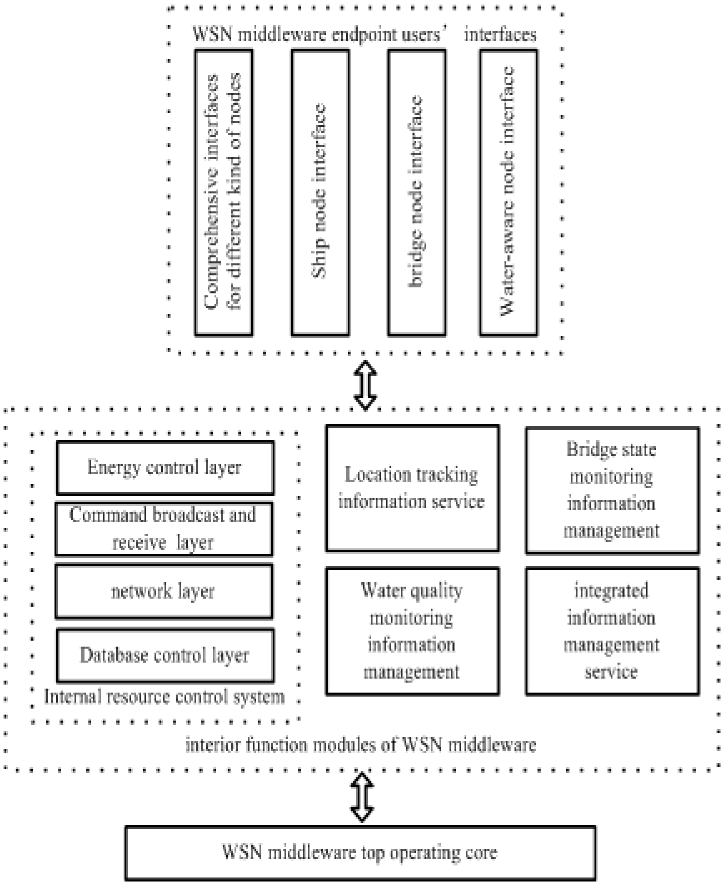

Figure 4. Architecture of WSN middleware system

6 CONCLUSION

This paper proposed a novel design of inland shipping management information system (ISMIS) for improving inland shipping management level. Since the design is based on wireless sensor network whose cost-effective is steadily higher the recent years, ISMIS can extend its supervising objects dynamically with the help of WSN, IOT, cloud computing, middleware technology and other IT techniques. Namely, inland shipping will be more efficient, real-time, and convenient than present inland shipping management system and inland ships will enjoy better information service in envisioned future with the establishment of ISMIS. In future we will pay more attention to the improvement and implementation of inland shipping intelligent management level using WSN and IOT techniques.

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