Research on Equipment Information Sensor Information Model System in Power Internet of Things

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Abstract. Power Internet of Things is the application of Internet of Things technology in smart grids. It is an important technical means indispensable for the construction of smart grids. In order to solve the problem of test data imbalance caused by the positioning deviation of the power sensor out of regulation point in the dynamic test system, A method for locating power sensor out-of-regulation points based on improved association mining algorithm (IMA) and FPGA implementation is proposed, and the association mining algorithm is analysed in detail. The paper uses the Monitoring Information Database (MNIB) to realize the organization and storage of power Internet of Things information. Designed a dedicated application layer communication protocol PIOTP, and developed a set of procedures, and finally established a standardized model of information interaction and a unique identification of equipment, so that data can be interacted with a unified information model in the network layer. The thesis completed the information transmission between the monitoring centre and the remote-control terminal (RTU), which verified the feasibility of the scheme.

Keywords: Power Internet of Things, equipment information sensor, information model, association mining algorithm.

1. Introduction
The State Grid Corporation of China proposes to accelerate the construction of a strong smart grid to achieve a highly integrated integration of "power flow, information flow, and business flow". Informatization is the basic way to build a strong smart grid. One of the keys to informatization is to carry out in-depth, multi-parameter integration, and collaborative processing of various information resources to provide more detailed engineering information for project planning, design, and production and operation stages.

With the comprehensive construction of the smart grid, the Internet of Things technology has been widely used in various business links. The Internet of Power Things is based on the overall architecture of the SG-ERP information system of the State Grid Corporation of China, including the perception layer, network layer and application layer, and has formed a power Internet of Things based on a unified information model, unified communication protocol, unified data service and unified application service Architecture. Among them, the perception layer realizes the unified
perception and expression of sensor data in each link of power production, establishes a unified information model, and standardizes the data access of the perception layer. The network layer realizes the transmission of data according to the standardized unified communication protocol. The application layer manages a variety of data information in a unified manner and provides unified data services to support various business applications. Based on unified application services, it develops various power Internet of Things application services for other business systems to call. This article focuses on the connotation, key technologies, definitions, modelling methods, etc. of the sensor information model of the perception layer, and provides specific examples to illustrate the application of the sensor information model [1].

2. Information Model
In the power Internet of Things system, the information transmitted between the monitoring centre and the remote-control terminal includes control instructions, monitoring data, equipment status, site description information, etc. This paper designs a monitoring information database MNIB to effectively organize and store information.

2.1. Monitoring object structure
The Monitoring Information Database (MNIB) is composed of several monitoring objects, and each leaf node in MNIB is a monitoring object. The monitoring object is the basic unit of the monitoring information database. It has 7 attributes, as shown in Figure 1. The identifier (ID) attribute is the only sign that distinguishes a monitored object from other monitored objects. It is represented in the monitoring information database in the form of "id1, id2, id3, id4", id1, id2, id3, and id4 each occupy a byte length, and the value range is 0-255 respectively. The type attribute defines the data type of the monitoring object.

Table 1 lists some commonly used data types in ASN syntax tags. The access authority attribute defines how the monitoring centre accesses the monitoring object. It includes four access methods: read-only, write only, read-write and inaccessible. The read-only mode means that the monitoring centre can only read the value of the monitored object; the write-only mode means that the monitoring centre can only write the value of the monitored object; the read-write mode means that the monitoring centre can both read and write the value of the monitored object; not The access method means that the monitoring centre cannot access the monitoring object. When the access authority attribute value is inaccessible, the monitoring centre cannot do any operation on the data in MNIB. The definition of this attribute can prevent the outside world from illegally tampering with the data in MNIB. The state attribute defines the current state of the monitored object in the RTU device, which includes three

![Figure 1. Monitoring object attributes](image-url)
states: mandatory, optional and obsolete. Mandatory status means that each RTU must contain the monitored object; optional status means that the monitored object can be selectively implemented on some RTUs; outdated status means that the monitored object has not been used in the RTU and can be used by others Replaced by monitoring objects. The definition of this attribute can remind the administrator to update the monitoring information database in time to ensure the timeliness of the monitoring information database. The object value attribute defines the value of the monitoring object. When the monitoring centre requests the monitoring object, it will be returned to the monitoring centre as part of the response message. The name attribute defines the textual name of the monitored object. The description attribute is a textual description of the specific role of the monitored object.

| Type of data          | Type description                                         | Tag value (hexadecimal) |
|-----------------------|----------------------------------------------------------|-------------------------|
| INTEGER               | An arbitrary integer                                     | 2                       |
| OCTETSTRING           | Arbitrary 8-bit value string                             | 4                       |
| NUL                   | Null value                                               | 5                       |
| OBJECTIDENTIFIER      | Object identifier, composed of a list of integers, used to determine the object, such as algorithm or attribute type | 6                       |
| SEQUENCE              | An ordered collection of one or more types               | 10                      |

2.2. Monitoring Information Base (MNIB)

Monitoring Information Database (MNIB) is a collection of all monitored objects in a monitoring station. MNIB uses a tree structure to classify and store data. It has a strict hierarchical structure starting from the root, consisting of a virtual root node and several branches and leaf nodes, as shown in Figure 2.

![Figure 2. Power Internet of Things monitoring information database structure](image)

The root node of the MNIB tree is a virtual node with no actual corresponding name and code. There are 4 branches under the root node, which are system information, real-time data, event records and metering information. There are three subtrees of plant information, RTU information and electricity meter information under the system information branch. There are 5 leaves in the plant station information subtree, which are the station number, station name, station location, contact person, and station phone number. The RTU information subtree has 6 leaves: RTU number, RTU
model, production plant, production time, execution agreement and number of meters. The meter information subtree includes four leaf nodes, including meter number, meter model, production plant, and production time. Each leaf node is a monitoring object. The monitoring object configuration information contained in the plant and station information subtree is shown in Table 2.

### Table 2. The configuration information of monitoring objects in the plant station information tree

| Monitoring object       | Object identifier | Object name | Object type          | status   | access permission |
|-------------------------|-------------------|-------------|----------------------|----------|-------------------|
| Plant station number    | 1.1.1.0           | StaNum      | INTEGER              | compulsory | Read only         |
| Plant name              | 1.1.2.0           | StaName     | OCTETSTRING          | compulsory | Read only         |
| Plant location          | 1.1.3.0           | StaPos      | OCTETSTRING          | compulsory | Read only         |
| Contact person          | 1.1.4.0           | contact     | OCTETSTRING          | compulsory | Read only         |
| Factory station phone   | 1.1.5.0           | StaTel      | OCTETSTRING          | compulsory | Read only         |

All nodes in the MNIB tree adopt hierarchical object naming rules, connecting the root node of the tree to all the node identifiers on the path of the node where the monitored object is located, and constitute the object identifier of the monitored object. The object identifier uses a 4-byte integer the sequence is represented by "." in the middle. For example, the object identifier of the station number in Table 2 is 1.1.1.0. The MNIB information model with a tree structure has the advantages of easy management and expansion, for any subtree or the addition, deletion, and modification of nodes will not affect other subtrees or nodes. In addition, when data is stored inside RTU, object identifiers in digital form are used. Digital storage consumes less memory resources, and storage the advantage of speed [2].

### 3. Power Internet of Things Architecture

The overall architecture of the power Internet of Things follows the “SG-ERP” architecture of the State Grid, which consists of a perception layer, a network layer and an application layer. As shown in Figure 3. The perception layer mainly realizes the collection, recognition and collection of information through various perception devices. The sensing layer is mainly composed of sensing equipment and monitoring units. The sensing information is transmitted according to the unified information model and communication protocol to realize the sensing of monitoring information. The monitoring unit automatically collects and processes the status data collected by the sensing device, and exchanges information with the concentrator. The network layer equipment adopts unified communication protocol for data transmission between the monitoring unit to the concentrator and the concentrator to the unified access gateway, which enhances the replaceability of equipment from different manufacturers and realizes the seamless access of perception equipment from different manufacturers. The unified communication protocol adopts the MMS of IEC 61850 in the IP environment to meet the data communication needs of the power Internet of Things. The network layer is composed of a concentrator and a unified access gateway. The concentrator collects information from the sensing devices sent by the lower receiving and monitoring unit, performs unified data intelligent processing and storage, and completes data communication with the unified access gateway. The unified access gateway receives and analyses the information of each concentrator, and sends the data to the processing program of the application layer.
The application layer receives the monitoring data uploaded by the sensing device from the unified access gateway, extracts, analyses, and processes and stores it. Based on the analysis results of raw data and data processing, provide unified data services for external applications. On the basis of data services, common business logic functions are extracted according to the business scenarios of each special application, and various special application services are developed in combination with the personalized function requirements of each special application to provide unified application services for external applications.

3.1. **IEEE 1451 networked smart sensor interface standard**

The IEEE 1451 standard defines a set of standardized universal interfaces for connecting sensors to the network, and establishes a framework for networked smart sensors, which enables sensor manufacturers to support multiple networks. Among them, IEEE 1451.1 defines a network-independent information model to connect the sensor interface with the network application adapter. It uses an object-oriented model definition to provide smart sensors and their components. IEEE 1451.2 specifies a digital interface to connect the sensor to the microprocessor, describes TEDS and its data format, and provides an independent 10-wire transmitter interface that connects the smart transmitter module and NCAP, so that manufacturers can use a The sensor is applied to a variety of networks, so that the sensor has "plug and play" compatibility. IEEE P1451.3 defines a standard physical interface index, which provides a standard for connecting multiple physically dispersed sensors in a multi-point setting. The IEEE P1451.4 standard proposes a mixed mode smart transmitter communication protocol based on the existing analogy transmitter connection method. It also specifies the TEDS format for the analogy transmitter with intelligent characteristics to interface to the legal system.

3.2. **Sensor ML**

Sensor ML provides a framework that can define the geographic, dynamic, and observational characteristics of sensors and sensor systems. The definition of atomic processes and process chains in Sensor ML enables a wide variety of sensor types to be supported. The goals of Sensor ML include: 1) Provide a description of the storage management of sensors and sensor systems. 2) Provide information on sensors and processes that support resource and perception data mining at the same time. 3) Support the processing and analysis of sensor perception data. 4) Support the geographic
positioning of monitoring values (measurement data). 5) Provide performance characteristics (such as accuracy, threshold, etc.). 6) Provide a clear description (that is, permutation) of the process of obtaining sensory data. 7) Provide an executable process chain that generates new data products on demand. 8) Archive the basic attributes and sensor system related conditions.

3.3. **State Grid Corporation Public Data Model (SG-CIM)**

The SG-CIM model is the public information model of the State Grid Corporation of China. It is developed on the basis of IEC 61970/61968. In the preliminary work, it has supported multiple scenarios such as asset life cycle, finance and transaction, audit innovation, etc. Business integration work. In order to further verify the usability of SG-CIM, support the construction of three sets of five major systems, and the in-depth application of smart grids, it is necessary to study enterprise-level business models. Enterprise-level business model refers to the unified planning and unified design of the company's business information models based on the public information model (SG-CIM) standard, forming an enterprise-level information model covering the company's various business areas. The purpose of information modelling in communication standards is to obtain the consistency and certainty of information transmission semantics. The model structure not only represents the abstract syntax in communication, but also represents the context structure of information semantics. The sensor information model modelling process is an information encapsulation process based on communication services. There is no complex model analysis and construction. It is described using XML-based SCL language, including the correspondence between information and communication services, and the reduction and expansion of information [3].

4. **Design of sensor information model based on power Internet of Things**

DB represents the global transaction database of the power sensor network, D represents the number of global transactions, let \( J_1, J_2, ..., J_n \) be the out-of-regulation point in the power sensor network, \( DB(i = 1, 2, ..., n) \) is the local transaction database of a single data stream of the power sensor out-of-regulation point \( J_i \), and \( D_i \) is the local transaction Number of articles, then

\[
DB = \bigcup_{i=1}^{n} DB_i, D = \bigcup_{i=1}^{n} D_i
\] (1)

In the power sensor network, the problem of locating the power sensor out-of-regulation point is how to mine the location of the local power sensor out-of-regulation point from n single data streams collected from n power sensor out-of-regulation points, and each node is connected through the power sensor network Transfer limited information, and finally find out the location of all power sensor out-of-regulation points in the global transaction database DB. In the positioning process, the existing problem is that the power sensor's out-of-regulation point is in a dynamically changing system [4]. When positioning it, due to the changing timeliness of the dynamic system, the positioning often deviates and the positioning is inaccurate. Existing methods have made little contribution to this problem. Due to the positioning deviation of the power sensor out of regulation point, the power sensor out of regulation point positioning model is shown in Figure 4.
4.1. Association Rules

There are a large number of nodes that can initiate the aforementioned expansion in the association rules, and many regional strong association trees are generated. When all nodes are included in each strong association area, the expansion ends, and then the correlation between the regions is analysed. Because the probability of strong correlation between regions is much lower than the probability of strong correlation between adjacent nodes, it is only necessary to determine that any two nodes between the two regions are not strongly correlated. The above two regions are non-strongly related, and the non-strongly related regions are quickly removed, and the strong related regions are finally obtained. After all the frequent node sets are collected, the corresponding association rules can be obtained [5]. The trust degree of the obtained association rules can be obtained by formula (2), and the conditional probability can be obtained by the support frequency of the node set

\[
\text{confidence}(A \Rightarrow B) = P(B|A) = \frac{\text{sup port}(A \cup B)}{\text{sup port}(A)}
\]  

(2)

4.2. DV-Hop positioning of power sensor out of regulation point

Based on the association rules of power sensor network nodes obtained in the above process, the DV-Hop positioning algorithm is used to realize the effective positioning of the power sensor out-of-regulation points. Considering that the distance between nodes cannot be directly measured, NICULESCUD et al. proposed the DV-Hop algorithm. The basic principle is: the distance between the unknown node and the beacon node, using the average per-hop distance between the nodes in the network and the distance between the beacon nodes the product of hops is described, and then the position of the node is obtained by triangulation. Although the number of beacon nodes acquired in the communication area of an unknown node is small, this method can be used to calculate the estimated distance of other beacon nodes outside the communication area and obtain the location information of the node. By broadcasting the information of all beacons, the number of hops from each node to each beacon node can be obtained, and the beacon node can also obtain the coordinates and the number of hops of the remaining beacon nodes, then the average distance per hop of the beacon node i can be used as (3) Description, its data packet format is \((id_i, c_i)\), namely

\[
c_i = \sum_{j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} / \sum_{j} h_j
\]  

(3)
In the formula, \( j \) is the remaining beacon nodes; \( h_{ij} \) is the number of hops from beacon node \( i \) to beacon node \( j \). In the process of calculating the distance, after the unknown node receives the data packets of all beacon nodes, it records the average distance per hop in the table, and then broadcasts it to its neighbouring nodes. If the same id packet appears, delete it. After the information broadcast is completed, the average distance per hop of all beacon nodes is calculated to obtain the average distance per hop of the entire network, which is described by \( cc \). The unknown node calculates the distance \( d_i = \text{Hopsack} \) between its current position and each beacon node and records it in the table.

4.3. Parallel structure design of power sensor dynamic locator

In the field of FPGA, distributed algorithm is a key technology, mainly used for digital signal processing and calculation. By changing multiplication operation into addition or shift operation, it greatly improves the efficiency of multiplication operation and enhances the chip's performance. Usage rate. Introduce it into the dynamic locator of this article and describe it as a convolution sum

\[
z(k) = \sum_{l=0}^{\infty} A_l y(k-l)
\]  

Among them, \( y(k-l) \) can represent

\[
y(k-1) = \sum_{b=0}^{B-1} y_b(k-1) \times 2^b
\]

In the formula, \( y_b(k-1) \) is the \( b \)th position of \( y(k-1) \), usually 0 or 1; \( y(k-1) \) represents the \( k \)-conversion result of the A-D converter. Substitute formula (5) into the formula (4) The output of the compensator can be obtained

\[
z(k) = \sum_{l=0}^{\infty} A_l \sum_{b=0}^{B-1} y_b(k-1) \times 2^b
\]

In the formula, the product term in square brackets represents the binary AND operation of one bit of the A-D conversion result and the positioning coefficient; the exponential factor represents the weighting of the value in the brackets.

5. Experimental results and analysis

In order to test the performance of the algorithm in the power wireless sensor network node positioning, simulation experiments are carried out. In the simulation experiment, the hardware system platform is: model Dell 2210b, the processor is Intel Core2 Duo 1.80 GHz, 1 G memory, and the main frequency is DDR2667. First, build a power network model. The simulation experiment is established under the MATLAB development environment. EVC software, that is, the embedded integrated development tool, is selected to simulate the development environment under different embedded hardware platforms. The use is compiled through the command line, and all operations must be performed under the command line [6]. Through the above processing and the simulation parameter design, the tap coefficient of the wireless sensor information fusion processing filter is 11, the signal time width is 0.5s, and the relative bandwidth is 0.8. The prior positioning errors are 2m, 1.5m and 1.5m respectively. The node energy scheduling scale ranges from 0.95 to 1.05, the interval is 0.0005, and the shift range is 35 to 65 ms. The simulation results of WSN node positioning distribution under different algorithms are shown in Figure 5.
It can be seen from Figure 5 that using the algorithm in this paper can effectively improve the accuracy of node positioning. Compared with traditional algorithms, the distance between the estimated position of each node and the actual position is smaller, and the positioning error of the out-of-regulation point positioning algorithm designed in this paper is smaller. The positioning time is faster. Through node positioning, the life of the power network is improved. In order to test its superiority, the comparison result of the life of the power network under the algorithm in this paper and the traditional algorithm is shown in Figure 6. It can be seen from Figure 6 that using the algorithm in this paper, by optimizing the positioning and deployment of power imbalance sensor nodes, the network life span is increased, and the superior performance of the algorithm in this paper is demonstrated [7].

### 6. Conclusion

This article mainly discusses modelling the sensor information model of the perception layer data of the Internet of Things, so that the data can be interacted with a unified information model in the network layer, which is mainly used to guide highly reliable and cost-effective smart sensors and standardized collection terminals. And the development of information model conversion equipment, and the formation of related standards and specifications. Through demonstration applications, the access of various sensor devices is standardized, and the data model is unified at the perception layer.
At the same time, it also lays a good foundation for data communication at the network layer, thereby promoting the continuous application of power Internet of Things in smart grids.

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