METADATA MODELLING OF THE IPv6 WIRELESS SENSOR NETWORK IN THE HEIHE RIVER WATERSHED

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ABSTRACT

Environmental monitoring in ecological and hydrological watershed-scale research is an important and promising area of application for wireless sensor networks. This paper presents the system design of the IPv6 wireless sensor network (IPv6WSN) in the Heihe River watershed in the Gansu province of China to assist ecological and hydrological scientists collecting field scientific data in an extremely harsh environment. To solve the challenging problems they face, this paper focuses on the key technologies adopted in our project, metadata modeling for the IPv6WSN. The system design introduced in this paper provides a solid foundation for effective use of a self-developed IPv6 wireless sensor network by ecological and hydrological scientists.

Keywords: Metadata, Ecology, Hydrology, Heihe River

1 INTRODUCTION

Environmental monitoring in ecological and hydrological watershed-scale research is an important and promising area of application for wireless sensor networks (WSN). Its potential to provide dynamic, real-time data about monitored variables in a landscape will enable scientists to measure properties that have not previously been observable.

The adoption of the next generation Internet protocol (IPv6) as the Layer-3 protocol to connect wireless sensors is a promising approach to address current issues of WSN, such as scalability, security, mobility, and so on. The IPv6 extended address space (2^{128} instead of 2^{32}) together with its auto-configuration and mobility capabilities makes IPv6 a suitable protocol for large scale sensor network deployments. Therefore, we designed and developed an IPv6 wireless sensor network to assist ecological and hydrological scientists to understand the watershed-scale hydrologic cycle and energy balance. The experiment area is the Heihe River watershed, which is a typical continental river basin starting in Qinghai province, going through Gansu province, and ending at the Inner Mongolia province in China.

The metadata in the IPv6WSN are descriptive data used to describe the IPv6WSN. This metadata include the environment, deployment location, data ownership, sensor specifications, sensor status, sensor calibrations and replacements, outlier and error information, etc., which play a crucial role in processing and properly interpreting raw sensor measurement and management data.

In our project, we define metadata as static, self-describing data for explaining IPv6 wireless sensor networks and node characteristics. We present a metadata model for the IPv6 wireless sensor network we developed for watershed-scale ecological and hydrological research. This model not only involves very rich scientific data but also includes the management and control data required by the IPv6WSN. Obviously, it is necessary to build such a unified metadata model for data transmission and processing. The metadata model introduced in this paper provides a solid foundation for effective use of a self-developed IPv6 wireless sensor network by ecological and hydrological scientists.

2 METADATA MODELLING

Metadata are structured information that describe, explain, locate, or otherwise make it easier to retrieve, use, or manage an information resource. Metadata are often called data about data or information about information. The metadata are generally used to describe and structure the principal aspects of the data with the aim of sharing, reusing, and understanding heterogeneous data sets and allowing the search and retrieval of information (National Information Standards Organization, 2004).

The metadata in the IPv6WSN are descriptive data used to describe the WSN, including the environment, deployment location, data ownership, sensor specifications, sensor status, sensor calibrations and replacements, outlier and error information, etc., which play a crucial role in processing and properly interpreting raw sensor measurement and management data.

Currently, the metadata need to become an important part of the WSN in order to preserve the knowledge of the WSN' status over time. The metadata must describe dynamically changes in the network status and report them back to other components and systems. For example, if a node changes its location, the system must be able to broadcast a message containing its metadata in order to inform other sensor networks and users about these changes. If a node fails, the network must automatically reconfigure new routes through which to send data. In the same way, if a node changes its location, the sensing data (and their metadata) must reflect the new location (Ballari, Wachowicz, & Manso Callejo, 2009).

In our project, we define metadata as static, self-describing data that explain IPv6 wireless sensor networks and node characteristics. The metadata model consists of six categories: *GeneralInfo, SensorInfo, Processes, Position, CollectedData,* and *ControlInfo*. Some of these also include sub-elements. The IPv6WSN metadata schema is shown in Figure 1.
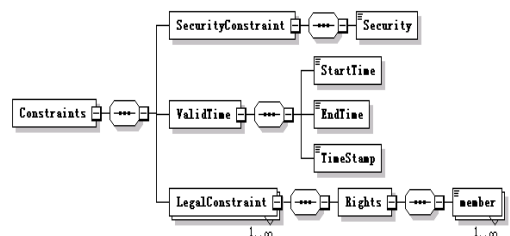

Figure1. IPv6 wireless sensor network metadata schema

2.1 GeneralInfo Metadata

These metadata include seven elements, which provide the main information to help users find wireless sensor networks, access monitoring data attributes, WSN owners' contact information, the constraints for use of the network, and so on. These elements include Identification, Description, Constraints, Properties, References, History, and SinkType. The detailed description is showed in Figure 2. Description metadata are used to introduce IPv6WSN supplementary information. Identification metadata include the name of IPv6WSN.
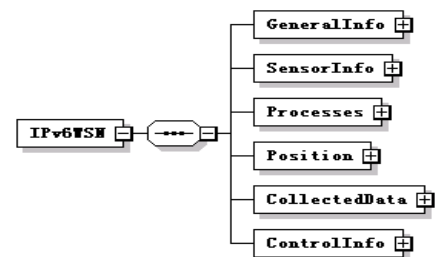

Figure 2. GeneralInfo metadata schema

Constraints metadata consist of three elements: SecurityConstraint metadata, ValidTime metadata, and LegalConstraint metadata (see Figure 3). SecurityConstraint describes the security requirements for use of IPv6WSN. ValidTime describes the time interval of the IPv6WSN operation. LegalConstraint is used to keep access only for registered members. This element has multiple members. If LegalConstraint does not exist, IPv6WSN can be used by anyone.
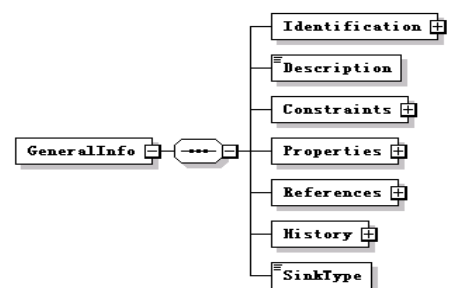

Figure 3. Constraints metadata schema

Properties metadata (see Figure 4) contain one or more attributes. All wireless sensor networks have their own attributes or characteristics, for example, a wireless sensor network can only collect radiation in a certain frequency range. The application of the network also needs to have some of the data quality requirements, such as acquisition accuracy. Some limitations on WSN in physics or mathematics can also be described in Properties metadata.
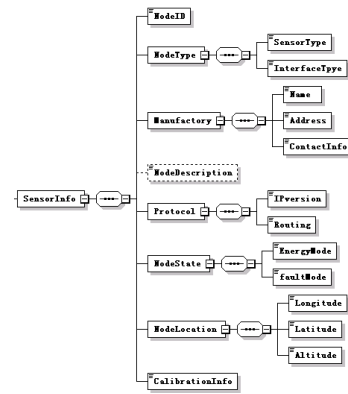

Figure 4. Properties metadata schema

References metadata (see Figure 5) include at least one Documentations element, which describes the information associated with wireless sensor networks, namely Description, Date, Contact, Format, and FileLocation. Each documentation element corresponds to a wireless sensor network with individuals or units, such as the wireless sensor network owner. Description describes the general information associated with the object. Date describes the time the document was produced. Format is the format used in the document.
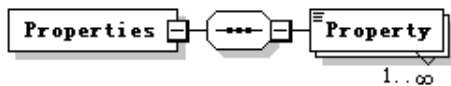

Figure 5. Reference metadata schema

History metadata record the general information and associated changes in wireless sensor networks, which contain one or more Event elements (see Figure 6). Each event has a date element (date), GeneralInfo element, and References element.
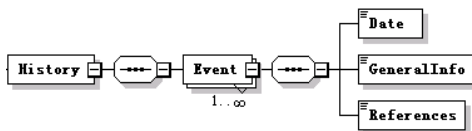

Figure 6. History metadata schema

2.2   SensorInfo metadata includes eight elements

The concept of this schema is shown in Figure 7.

NodeID is the unique ID of the specified sensor node. NodeType includes the type of sensors carried by the node and the interface conditions. Protocol element reflects the network protocol used by the node, for example, the IP version (IPv4 or IPv6). NodeState describes the node's energy mode (active or sleep) and operation state (good or fault). NodeLocation includes the node's geographical information. CalibrationInfo records the calibration information, which is very important for improving the sensor accuracy.

Figure 7. SensorInfo metadata schema

Processes metadata

Processes metadata (see Figure 8) include at least one process element. Each process represents a process that a wireless sensor network can perform. As the wireless sensor node has the computing power, a small node with a variety of sensing devices can make some analysis and processing on the physical sensing value. The output is the value processed by the node, for example, the average temperature over time. Process metadata include input, output, and parameters. Input represents the physical phenomena in the natural world the wireless sensor network can sense. Output represents the values after the wireless sensor networks process the original sensing data. Parameters describe the requirements or conditions of the process. For example, the frequency of data collection cannot be less than 2 seconds or the nodes would communicate with each other during the conflict. Parameters are associated with the characteristics of specific wireless sensor network nodes.
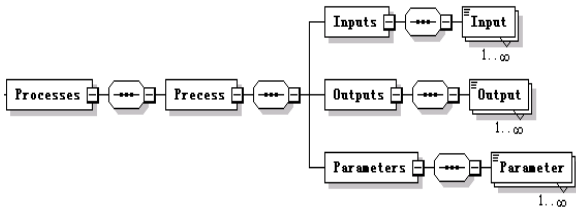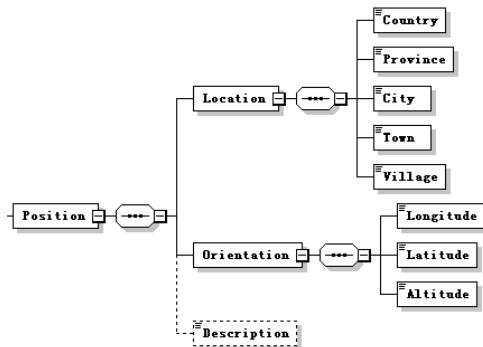
Figure 8. Processes metadata schema

2.3   Position metadata

Position metadata are used to describe the geographical location of wireless sensor networks, which includes location element, orientation element, and an optional description element (see Figure 9). The location element describes the location information according to administrative division including country, province, city, town, and village. The orientation element includes longitude, latitude, and height. In addition, an optional description can be used to introduce the general information of the wireless sensor network deployment area.

Figure 9. Position metadata schema

2.4   CollectedData metadata

CollectedData metadata (see Figure 10) describe the available data sets collected by the IPv6WSN. In our project, the scientific data that need to be collected in the field are mainly multi-disciplinary, multi-scale space-time meteorological, hydrological data, including Lysimeter, Bowen ratio, cosmic rays, soil temperature and moisture profiles, soil heat flux, soil water potential, infrared surface temperature, precipitation, temperature, wind speed, humidity, shortwave radiation, 2cm/5cm/10cm soil moisture and temperature, snow depth, and so on. CollectedData metadata include DataName element, DataType element, DataLength element, Unit element, CollectedTime element, and DataDesctiption element (optional).
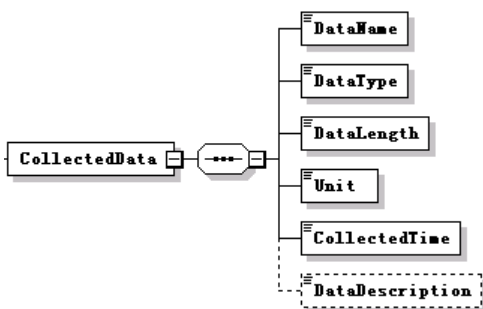
Figure 10. CollectedData metadata schema

2.5   ControlInfo metadata

In our project the sensor node not only collects field data but also can be controlled as needed. ControlInfo metadata describe the control instructions or commands sent to the sensor node, including NodeID element, SendTime element, and ControlType element. (see Figure 11)

Figure 11. ControlInfo metadata schema

2.6   Software system based on the metadata model

Based on the above metadata model, a software system responsible for data management and processing in IPv6WSN is developed (see Figure 12). The programming language is C#, and the development platform is Visual Studio 2008.

Figure 12. View of the software system

3   CONCLUSION

In this paper, we present a metadata model for an IPv6 wireless sensor network that we developed for use in watershed-scale ecological and hydrological research. This model not only involves very rich scientific data but also includes the management and control data required by the IPv6WSN. Obviously, it is necessary to build such a unified data metadata model for data transmission and processing. The metadata model introduced in this paper provides a solid foundation for the effective use of a self-developed IPv6 wireless sensor network by ecological and hydrological scientists. The conclusion should indicate the significant contribution of the manuscript with its limitations, advantages, and applications.

4   REFERENCES

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