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Wireless Sensor Networks Database: Data Management and Implementation

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Abstract: As the core application of wireless sensor network technology, Data management and processing have become the research hotspot in the new database. This article studied mainly data management in wireless sensor networks, in connection with the characteristics of the data in wireless sensor networks, discussed wireless sensor network data query, integrating technology in-depth, proposed a mobile database structure based on wireless sensor network and carried out overall design and implementation for the data management system. In order to achieve the communication rules of above routing trees, network manager uses a simple maintenance algorithm of routing trees. Design ordinary node end, server end in mobile database at gathering nodes and mobile client end that can implement the system, focus on designing query manager, storage modules and synchronous module at server end in mobile database at gathering nodes.

Keywords: Database, Network, Wireless sensor.

1. Introduction

With wireless communication technology, embedded calculation technology and sensor technology in further development, wireless sensor network that consisted of a large number of intellectualized sensor node and got energy by the batteries with wireless communication ability began widely to emerge in national military, environment monitoring and manufacturing in all of scientific research and social living fields [1]. With the gradual development of hardware design technology, these sensor node points is not only able to receive the perception data from realistic world through corresponding sensors, but also able to filter, gather and cache effectively to the sense data received, took full advantage of the characteristics of net inner treatment, perceived sense data to the users in need by sensor network with energy efficiency mechanism. Any application system based on the wireless sensor network is inseparable from the management and process in the perception data [2]. Sensor network is a data-centric network whose basic idea is to regard the sensor as sense data stream or sense data source, take the sensor as perception data space or perception database, keep the data management and process as the aim of network application.

A wireless sensor network contains a large number of sensor node points; each node collects perception data at certain times according to inquiry need. In order to store and manage perception data, it is necessary to build data processing models for awareness data. The perception data models should

be convenient and conducive to the description and implementation operation in perception data inquiry [3]. Since perception data is the stream data by continuous collection, we can perceive data stream as an append only virtual table, in physical, the whole virtual form is located in each node device in network, so it can be seen as a distributed database system with many perception data tables. Wireless sensor network data distributes and stores on all nodes, builds the internet connection between storage nodes, constitutes a distributed database. In order to achieve the inquiry of data in the wireless network at any time and any places, we can design a mobile database based on the characteristics of wireless sensor network data to make the data inquiry of sensor network go out the limitation of fixed cable networks, obtain and process sensor network information at any time and any places. The ultimate goal of data management in wireless sensor network (WSN) is to support efficient and reliable data storage and access in the heterogeneous, unreliable network, and to make full use limited resources of the nodes, and to provide users with low latency services. Data storage mainly studies how to save sensory data in the network effectively in order to make user obtain perception data easily and quickly. Data access mainly refers to using the efficient storage method to realize the high efficiency and energy saving query processing.

Typical wireless sensor network (WSN) is shown in Fig. 1. A large number of multimedia sensor nodes are deployed randomly and evenly in the region which is need of monitoring. Every multimedia sensor node has functions such as wireless communication, computation and storage, etc. They can spontaneously form a multihop data transmission network. When receiving the data collection command released by task management node, various multimedia sensor nodes will begin to collect data, and transmit the data collection results to gather nodes Sink along the data forwarding path established. Gathering node Sink sends the final monitoring results to task management node by the Internet or satellite.

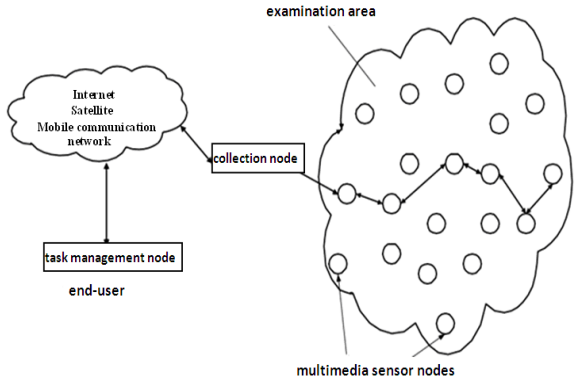

Fig. 1. Diagram of wireless sensor network.

2. The Data Storage of Wireless Sensor Networks

Data storage in a wireless sensor network researches storage strategy in the network of perception data produced by node, including how to store the data in their proper locations in network and how query request is routed to the storage location for the data. This is actually a process of information intermediary. Information mediation refers to the producer will save sensory data in a specific position according to certain strategy, and consumers (may be a base station, also may be a sensor node) route data access request to the storage location of relevant data in accordance with the corresponding strategy, then feedback results which satisfy the query conditions to customers. According to the different storage strategy of perception data, data storage can be divided into centralized storage, local storage, distributed storage and sensor network database. Next the four strategies will be discussed respectively.

1) Centralized storage: Centralized storage is one of the most simple data storage strategies. Each node transmits the collected perception data to base station (sink node) for storage, and data access gets the data directly from the station. As a result of unlimited energy and storage space of the base station, data can be preserved for a long time, and data access will not consume the energy of the nodes in the network. The sensor network is only as a means of data collection rather than data processing, because the user can only get the data in the database from the base station. In addition, when the network scale is very large and node's distribution is dense, large amount of data need to be transmitted in the network, then the nodes near the base station will consume energy quickly by transmitting data. At last, it can constitute a bottleneck to the network, so this method is not suitable for large-scale network.

2) Local storage: Local storage refers to the node's perception data being stored in it storage, and data access request is routed to all nodes to obtain relevant data. This strategy will transmit the query request to the entire network, and each node feedbacks the results according to the query condition. Its advantages are that data storage is simple and stored procedure is without any communication overhead, and data access is a kind of on-demand query. Its shortcomings are as follows: first of all, the node's storage capacity is limited, so it can't save the historical data for a long time. Once a node fails, the data will be lost. Secondly, using the flood routing, query request is transmitted blindly in the network, so network's life will be shorted because of large energy consumption, so it does not apply to the network in which query requests happen frequently. Finally, the cost of data transmission is high and query processing is more complex.

3) Distributed storage: Distributed storage is a data-centric storage strategy. Its core idea is that the sensory data from node is not always stored locally but also stored in other nodes by the distributed

technology, and adopt effective information mediation mechanism to coordinate the relationship between the data storage and data access, so data access requests can be satisfied. Under this strategy, data is stored in accordance with the specific storage mechanism, and query request obtains the data according to the specific access mechanism. These mechanisms include: hash map, indexing, data and query request being routed according to certain rules, etc. Its advantages are: the distributed data storage is consistent with the distribution of sensor network, and the information intermediary mechanism can ensure that the data access requests are satisfied. The disadvantage is that information intermediary needs extra cost.

4) Sensor network database: Sensor network database integrates the above three strategies. It integrates the traditional database technology, distributed technology and network technology closely. The sensor node is regarded as a perception data flow or data source. The wireless sensor network (WSN) is regarded as a distributed database. It can achieve a sensor network database system which is data-centric with high performance using the logic concept and software and hardware technology. Sensor network database is complementary with data-centric routing. Relative to the data storage and access, routing is bottom-up, but relative to data modeling and database access, the database is top-down.

Data storage methods in sensors network are divided into three kinds generally: 1) External storage: Data are stored in centre treatment equipment out of sensor network together. (The base station or gateway) 2) Local storage: Perception data after production are stored in sensor node. 3) Data-Centric Storage: Name the perception data, and store in specified position in sensor network according to the name of perception data [4]. External storage is in the centralized structure, all perception data are stored in convergent nodes of external sensor network, that is to say, after sensor nodes get monitoring data, no matter whether convergent nodes interest in the data, they are sent to convergent nodes actively. When local storage methods are used, all perception data are stored in sensor nodes that produced the data, i.e. at first the sensor node stores monitoring data in local store, the relevant data is sent to convergent codes after receiving enquiry commands.

Using external storage methods, sensor nodes transfer all collected data to central node to analyze and process by prior appointed ways, though storage is sample, the cost of communication is expensive, and central and surrounding codes will become the bottlenecks for system performance, and meanwhile it may take some data that not needed to central nodes to cause waste [5]. Using local storage methods, storing perception data does not need to consume extra communication energy, data through network transmission are with interested by convergent nodes, but it takes lots of energy in data the query [6]. The cost stored around the data is between the two factors.

3. The Data Query of Wireless Sensor Networks

3.1. The Structure of Data Management System

At present, the structure of data management system on transducer network is divided into the following four categories: Centralized structure, Semi-distributed structure, Distributed structure and Hierarchical structure.

1) Centralized structure.

In centralized structure, the inquiry of sense data and the access of sensor network are relatively independent. The whole process is divided into two main steps: At first, sense data will be perceived to the central server by specifying methods from the sensor network, and then conduct the query treatment in the center server. This method is simple, but the center server will be the bottlenecks in system performance, and fault tolerance is poor. In addition, because the sensor data are required to the center server finally, communication expenses are very large.

2) Semi-distributed structure.

As sensor nodes have the calculation and storage function, it can deal with original data on certain degree. Now most of the research concentrated on semi-distributed structure.

3) Distributed structure.

Distributed structure assumes that each sensor has very high storage, calculation and communication ability. Firstly, each sensor samples, perceives and monitors cases, and then uses a hash function, stores them to the sensor nodes near to the value of the hash function by the keyword of each event, which is called hash function [7]. Processing the query, the same hash function is used to send the query to the nodes near to the value of hash function. This structure will put computation and communication at the sensor node points. The problem of distributed structure is to assume that the sensor node has the same calculation and storage ability with ordinary computers, distributed structure is only suit for the inquiry based on event keywords, and the communication costs of system is much.

4) Hierarchical structure.

Against the shortcomings of above system, make a kind of hierarchy structure, as shown in Fig. 2.

This structure contains two levels: the sensor network layer and agency network layer, and integrates multiple technology: the intra-network data processing, adaptive query processing and the query processing based on the content. In the sensor network layers, each node has a certain calculation and storage ability [8]. Each sensor node finishes three tasks: Receive orders from the agency, carry out

local terms, and transmit the data to the agency. The orders that sensor nodes received included sampling rates, transferring rates and processing that needed to perform. The nodes on the agent layer have a greater storage, computation and communication ability [9]. Each agency completes five tasks: Receive enquiries from users, send control orders or other information to the sensor nodes, receive data from the sensor nodes, process queries, and return the results of inquiries to the users [10]. After the agency nodes received the data from the sensor nodes, a number of agency nodes handle the results of enquiries at some steps and return the results to the users. This method distributes computation and communication tasks to all of the nodes.

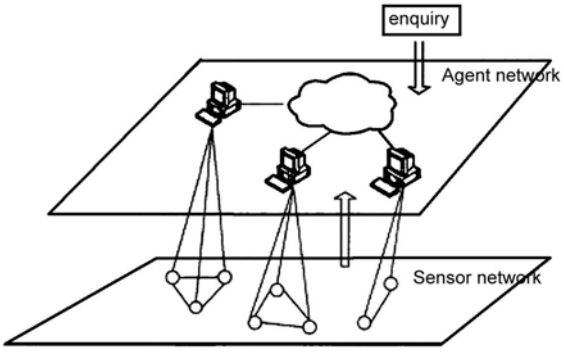

Fig. 2. Hierarchical structure.

3.2. Query Processing and Optimization

First of all, query processing in sensor networks needs the support of the underlying routing protocol. It is assumed that the routing tree has been established by under layer to support query access. A query process is released from the top to down, then the root node transmits query requests to the child nodes, and the child nodes use broadcast mode to send requests to its child nodes continuously until arriving to the leaf nodes. The result is collected from the bottom up. Firstly a leaf node sends the result to the parent node, and the parent node sends it upward continuously, until the result is fed back to the root node which has put forward the query requests.

After the query request arrives to the node, the query processor of node or query proxy is responsible for executing it. Query processing includes two stages: pretreatment and execution phase. Preprocessing stage mainly checks the legitimacy of the query request and prepares for query execution work. Although the validity check work is mostly done on the base station side, but because of the dynamism of network, the base station side cannot have all the nodes' information in time, so some legitimacy examination work is transferred to individual nodes. Preparation is mainly to establish an internal data structure and allocate necessary storage space for query execution.

Query execution is generally divided into four stages: starting stage, operator's execution stage, results transfer stage and state transition stage. In the beginning of each round, the query enters into the start-up stage, and the sensor's perception component collects data, and then computes the sensory data based on the operator's sequence in the query plan and transfers the results by the routing tree. After the transmission, nodes enter into a dormant state through state transition phase. If no results are transferred, nodes directly enter into the state transition stage from active state to dormant state.

In order to save energy, system must weigh all kinds of cost to produce a plan for the query in the process of query processing. The query plan assigns different roles to different nodes in order to undertake different task in executing queries, and schedule different nodes for data communication. If not scheduling, node does not know when to start receiving data from neighboring nodes, so most of the time it is in the listening state, and consumes the valuable energy. So try to adopt a variety of optimization strategy in the process of query processing in order to reduce the communication cost and save energy consumption.

4. The Design on System

4.1. The Manager of Sensor Mode

Components structure of engine is shown in Fig. 3, sensor mode manager is in charge of managing the sensor mode of database. We transfer the sensor model to virtual "database table", mode contains commands that the system can use and the subprogram in updated and queried table as the formal description of sensor table. The table doesn't only contain various types of properties, but also includes a group of references associated with executable order sets on query actuator. The groups of references are similar to the method of expanding SQL in database system of relative objects. In the query processing, put the data from sensor on each node into a tuple, these tuples can be transferred between the nodes of many routing, or gather data, or express code to server-side from the serial of network tip. Sensor mode manager includes some components: Attr, Command, WsnMDBAttr, Tuple, WsnMDB Command, QueryResult. The function of Attr is ix and to get property values; The functions of Command are to achieve various orders in the mode; WsnMDBAttr is the concentrator of properties to connect various fixed property components in the database. When the components are increased to achieve new intrinsic of the database, WsnMDBAttr needs to be updated. WsnMDB Command is also the concentrator of properties to connect various fixed property components in the database. When the components are increased to achieve new commands of the database, WsnMDB Command needs to be

updated. Tuple elements contain a variety of programs with tuple data structure in the management database. Query Result implements the transition of data structure between tuple, Query Result, and byte strings. A tuple are equivalent to a row in the relationship table, and Query Result contains a tuple and some metadata, such as id number, index, etc. Data types of mode manager Schema show in Table 1.

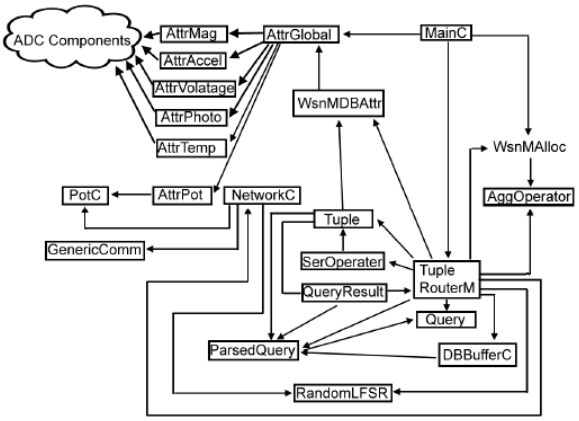

Fig. 3. Components structure of engine.

Table 1. Data types of mode manager Schema.

Data types	Definition
Void	Used to define the command without back content
INT8 and UINT8	Eight bit integer with marks and without marks
INT16 and UNIT16	Sixteen bit integer with marks and without marks
INT32 and UNIT32	Thirty-two bit integer with marks and without marks
STRING	ASCII character strings rather than at the end

Query processor in database is responsible for the completion of the query processing, and the usage of storing information in the sensor catalog to get the property of sensor nodes, such as reading data from the sensors, aggregating and optimizing, and then sending the data to the master node [8]. In database, the main elements that are responsible for the parts of work are the three components: TupleRouter, SelOperator and AggOperator. Tuplerouter components provide the main query processing function in sensor node, it passes tuples between various sensor query processing components, so called “a router”. Tuplerouter is not responsible for the network router, it is mainly responsible for processing query information as the core of database system, TupleRouter runs in a single sensor node, including the receiving to new arrival enquiry information and analysis of it in details: Receive the results information of adjacent nodes and make local processing; and transmit dealt data to the root node. It got enquiry from the network, produced local state for them, i.e. transferred the queries to enquiries through the syntax analysis, and got results from the local sensor node and neighbor node to provide queries which contains selection and aggregates, the results from queries without operation together are sent to the root node of a tree simply and treat by query processor of root node.

In running process, the database engine receives continually some news packets belonging to a query from a network module (NetworkcC components). In the receiving and grouping process, nodes create a Query data structure to describe the query in the construction. When it received all the news packets of a query, a complete Query structure was established, the database engine analyzed the query according to the metadata information on nodes, built a ParsedQuery structure in the description of enquiry and execution state, and added it to the queue of the maintenance for engine, prepared to carry out or carry out after corresponding cases happened. After queries start, start the implementation periodically. In the query execution, leaf nodes collect data that query needs, filter by the predicate condition (SelOperator components), and send the required data to the father nodes; the middle node of routing trees will repeat the operation of the leaf node, if it needs an aggregation or grouping (AggOperator components), and carry out the operation to the received data and its own data, the data is returned to gather nodes in the end of each cycle.

4.2. The Network Module of Database

Database network manager is responsible for the network management and the maintenance of a routing tree so as to communicate between sensor nodes and convergent nodes, nodes and nodes. Each node in network maintains a neighbor node table, and chooses a best node as a father node to form routing tables. The database ensures that each node in network can deliver its data to users in an efficient and reliable way by capturing neighbor nodes and maintaining routing tables. Database uses Network interface to capture and control network communications, the TuplerRouter of query processor only connects the Network interface by proper Am sending and references, topology and filtering events of the network controller adopt a half-intelligent way to work.. As for the data messages: First of all, verify efficient payload of the data message, and then call send Data Message to choose to his father nodes by the routing protocols of many jump transmission, send a message with tuples to the specified address. After data messages have finished, it would trigger a finished case. As for the enquiry messages: First of all, verify efficient payload of the data message, and then call an send Data Message request enquiry in nodes, finally broadcast part of message with enquiries to his neighbor nodes. The enquiry message has finished, and then will trigger a

finished case. A tuple or a data message receives data from the neighbor nodes and triggers an event received. If a message is not listened, it will trigger an event.

Most of program codes in network manager are used to manage the structure of network topology. The structure of network topology in database is a routing tree. The sensor node that ID number is 0 is the root node. A network manager is equivalent to the routing components in a database to receive data, transmit data and query massages, data messages is gathered data or tuple, the query messages represents the part of query into the network. Query news is broadcasted to the routing trees, the enquiry requirement passes down from root nodes, data messages propagates up to the root node of the network. The tree node is in charge of transferring the query results to convergent node in the server side and application programs. In order to achieve the communication rules of above routing trees, network manager uses a simple maintenance algorithm of routing trees. The algorithm makes each sensor node keep a neighbor table, and selects a node in the neighbor nodes as its father node in routing trees.

5. Conclusions

This article researched the design of database system based on wireless sensor network management referring to data management in wireless sensor network. Provide the system structure of WsnMDB and all the functional modules and research deeply the historical storage method of data stream in wireless sensor network, adopt the management method with the combination of sampling storage and gathering value storage to historical data in data stream to support the gathering enquiry to the historical data in data stream. Design ordinary node end in wireless sensor network, server end in mobile database at gathering nodes and mobile client end that can implement the system, focus on designing query manager, storage modules and synchronous module at server end in mobile database at gathering nodes.

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