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Multi-level Feeder Queue Optimization Charging Model of Electric Vehicle and its Implementation of M-R Algorithm

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Abstract

Recently, issues of energy shortage and environment pollution of mankind society become more and more serious. Production of electric vehicles provides a new idea for mankind to solve this kind of issues. However, large-scale electric vehicles put into operation and connected to the grid is a major challenge to the security and stability of power grid. This paper references the job scheduling algorithm in computer operator system and presents a multi-level feeder queue optimization charging model with comprehensive consideration of the grid-side power load and charging fairness. According to this model we charge for the electric vehicles in regional grid, on the basis of ensuring fairness, realizing optimized charging, to ensure grid security and stability and improve the resource utilization rate. The implementation of multi-level feeder queue optimization charging model of electric vehicles in regional grid requires the fusion of power grid, cars networking, charging station networking and other information. With the development of the industry, the integration of multiple information sources will produce massive heterogeneous data, showed a trend of big data, and its storage and calculating will become a bottleneck. Hadoop open source cloud computing platform can set computing cluster to implement such a big data parallel processing. In this paper, I implement the model in the cloud computing platform through designing the model's HBase distributed data storage and M-R parallel computing mode.

Keywords: *Electric Vehicle, Big Data, Multi-level Feeder Queue, Hadoop, Cloud Computing*

1. Introduction

The development of community economy faced the constraints of fossil energy shortage, ecological environment deteriorate and other factor. As a new clean energy kind of vehicle, electric vehicle produces an outstanding effect on the side of reducing pollution and consuming of fossil energy. Developing new energy vehicles, realizing transportation energy comprehensive transformation has become the measures of the strategy of sustainable utilization of energy, low carbon economy transformation and the construction of ecological civilization. However, Electric vehicles bring the opportunities as well as a series of challenges to the power grid load, planning, power quality, the traffic and so on. Large-scale electric vehicles charging during the same period will bring a new round of load growth, especially charging in the load peak period will further aggravate grid peak valley load difference, which may lead to a series problem such as line overload, transformer overload [1], voltage drop[2-3], loss increase[4] and so on. In addition, because of the uncertainty of the charging and the difference of charging type, the charging load has the characteristics of randomness and dispersion, which will also increase the difficulty to operate and control the power grid[5]. Therefore, the optimized control of the electric vehicle charging is of great significance to ensure the safe operation of the power grid, to increase the energy utilization and to maximize the benefits [6].

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Considering the grid load, economic benefits and user fairness, the optimal charging scheme should realize centralized monitoring and unified deployment for all charging stations and the electric vehicles in a certain area. In recent years, more and more researchers did lots of explorations on the electric car charging model, which developed various optimization solutions from different aspects. From the aspect of research, solutions can be divided into three categories: (1) Charging control of single electric vehicle; (2) concentrated charging control of more cars in the same station; (3) coordination control of multiple stations in a certain area. According to the power flow, researches can be divided into: (1) Single direction charging control, only the charging from grid to car is considered; (2) the V2G mode [7]. In this mode, two-way power flow between the battery and power grid, and the electric car can feed power to the grid [8].

Multi-source fusion of the information from grid, charging stations and electric vehicles contributes to the implementation of different optimized charge control schemes. With the development of electric vehicle, more and more charging stations will be established [9]. Therefore, it is necessary to manage the huge amounts of heterogeneous data, which puts forward high requirements to the large data processing to control center and data center. Cloud computing, a distributed parallel processing platform large, assigns amount of computing tasks to a computer cluster, which is able to efficiently and accurately deal with big data problem [10]. Owning to the strong capacity in resources allocation and data processing, cloud computing platform has congenital advantage in big data processing. What's more, how to apply cloud computing platform to optimize charging control of electric vehicles is the focus of this article.

In order to realize the optimized charging of electric vehicles, a multi-level feedback queue optimization model of electric vehicles charging is proposed in this paper, which combines the job scheduling optimization algorithm of computer operating system and multi-source fusion technique of information. In addition, this optimization model is realized by M-R parallel algorithm on the cloud computing platform.

2. Multi-level Feeder Queue Optimization Charging Model of Electric Vehicle

2.1. Analysis of Model Need Target

Electric vehicle charging in the regional power grid is a process of interaction among the grid, the charge operators and the users of electric vehicles, is a two-way transmission of the energy flow and information flow. Creating optimum charging strategy plays an important role on all sides and is also a process of considering various factors. To put forward the optimization charging model, we need to deal with three relations. First, the relationship among the government, enterprise and market. Second, the relationship among the products, infrastructure and business models.

Third, the relationship among the users, electricity companies and charging operators. What the electric vehicle users more considered are the time, price, convenience and so on. But the electricity companies and charge suppliers have more consideration of the safe and stable operation of power grids, energy efficiency, fair service and other factors. Ensure the user fairness is one of the most important goal of charge services which related to the implementation effect of the orderly use of electricity. The user fairness is especially obvious at the time of a user has a emergency transport demand. If we do an orderly charging control without considering user fairness, it may occur a large number of power supplies "zero" phenomenon when the users have emergency transport demands, which will serious influence the user's normal use. And it is the ultimate goal of optimizing charging to ensure stable operation of grid and improve energy utilization rate.

Therefore, we need to consider that on the premise of guarantee the user fairness, trying to make early access, large power and large initial SOE users charge in high priority. We should also consider that use price leverage to encourage users to extend the charging time, so that it is easy to adjust the charging time and optimize the charge. Here I considered various relations, according to the requirements of all sizes, to establish a multi-level feedback queue optimization charging model in regional power grid.

2.2. Multi-Level Feeder Queue Based Optimization Charging Model's Establishment

In computer operating systems, there is a scheduling application scenarios that a large number of jobs simultaneously request limited resources at the same time, how the system scheduling thus orderly allocate resources to the jobs. Here I reference the operating system's job scheduling solutions to achieve electric vehicle charging task scheduling. With each electric vehicle charging task as a job, the charging energy as resource, the minimum load energy as the goal, my solution legitimately arranges the jobs execution order, so that improve resource utilization under the premise to ensure fairness.

Multi-level feedback queue process scheduling is now recognized as a good scheduling algorithm which dynamically adjusts priority and time slice size, from a more micro level to maintain maximum fairness and enhance the efficiency of resource utilization. Multi-level feedback queue charging model learns from this scheduling algorithm, in the premise of ensuring all users complete charging before booking time, according to the charging urgency, charging duration, the access time, waiting time and other indicators, determines multiple priority charging queues. The entire charging process is divided into several fixed-length "time slice". For each queue, model sets a different length of time slice. After the end of each charging time slice, model will recalculate priorities in order to adjust the queue elements.

Figure 1 is the whole architecture figure of multilevel feedback queue optimization charge model.

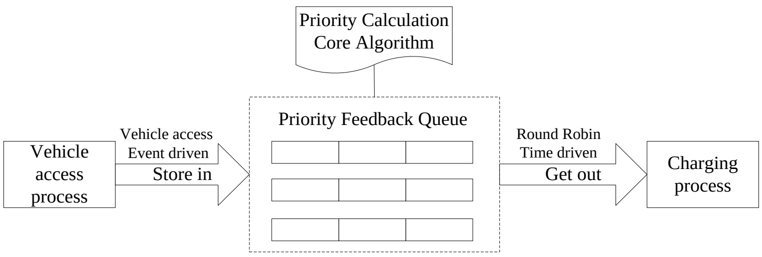

Figure 1. Whole Architecture Figure of Multilevel Feedback Queue Optimization Charge Model

Multi-level feedback queue optimization charge model scheduling algorithm is divided into the following steps:

(1) For the charge task that can be adjusted (charge time is less than the length of time set by the user), calculate the task priority. Priority should be considered the urgency of charging, charging time, waiting time and other factors, therefore, this paper proposed the equation (1) to calculate the priority.

$$R = \frac{W + T}{T * [(T_U - T_C) - T]} \tag{1}$$

Among them, T is the remaining time needed to charge, W is charging wait time, T_U is the take up time set by user, T_C is the current time. $(T_U - T_C) - T$ shows the difference between the remaining charge time and the limit user set, which can reflect the degree of urgency of charging task. With the charging progresses, T gradually becomes smaller, W gradually becomes larger, and $(T_U - T_C) - T$ gradually becomes smaller. Thus, the charging task with more urgent and longer time waiting, its priority will be adjusted higher, so that be implemented first.

(2) According to the priorities, set multi-level queue. The tasks should be sorted by the priority, and divided into multi-level queue according to priority range. Specify a particular time slice length for each queue, which the higher the priority, the shorter the time slice.

(3) Charge for the task in the highest priority queue. By the end of each time slice, each task priority should be recalculated, so that reclassified the queue.

(4) When the high-priority task charging is completed, it can be charged for the next priority task queue.

Figures 2 and 3 are vehicle access process and vehicle charging process. Among them, vehicle access process is event-driven, which vehicle access event activated the process, and then the charge task is stored in the charging priority queue. Vehicle charging process is time-driven, which time slice continuously rotated, each time slice rotate end, take out task from the priority queue and charge, and recalculate the priority queue.

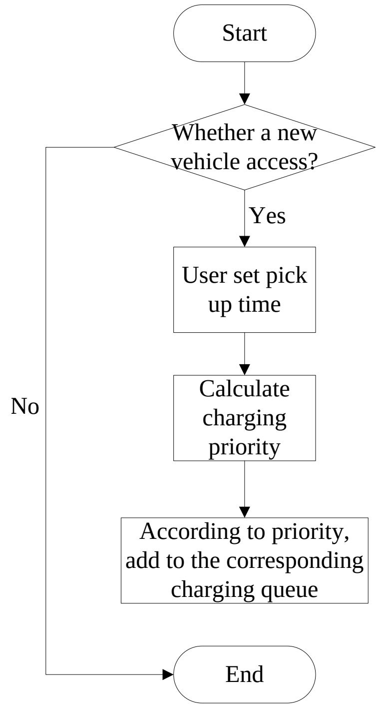

Figure 2. Vehicle Access Process

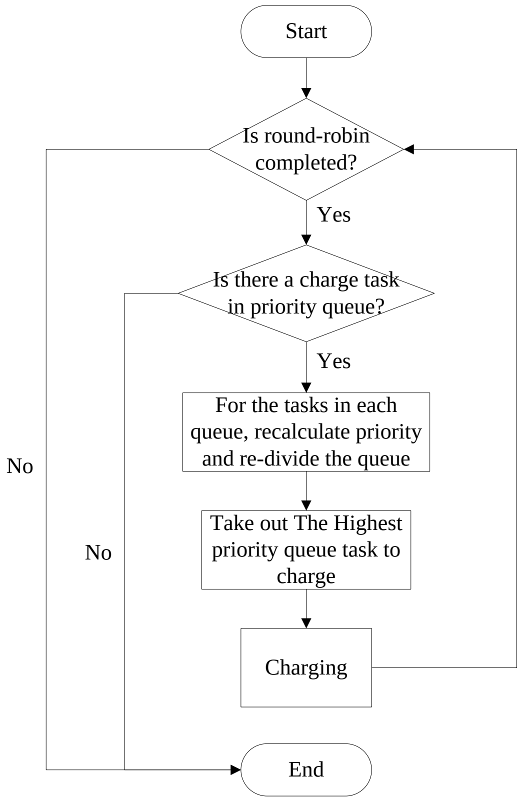

Figure 3. Vehicle Charging Process

Multi-level feedback queue optimization charge model not only considers the principle of user fairness, but also can minimize the impact on power load by real-time control of the charge pile, so that ensure the stable operation of the power grid.

3. Cloud Computing Platform Based M-R Algorithm Implementation of Multi-Level Feedback Queue Charge Model

3.1. Problem Analysis of Multiple Information Sources Integration of Electric Vehicles in Regional Power Grid

The implementation of multi-level feedback queue optimized charge model requires the integration of grid load information, charging station parameter information, car battery information, user information and other information in regional power grid. And during the information convergence process, we need to consider the following questions:

(1) Problem of heterogeneous data dealing caused by integration of multiple information sources.

(2) The mass data storage problem, which collected from large-scale, decentralized electric vehicles and charging stations.

(3) Large computation problem caused by complex calculation of multi-level feedback queue optimized charge model.

(4) Real-time requirement problem for user demand for charging scheme results.

Multiple information sources caused by electric vehicle optimize charging calculation in regional power grid show a trend of big data. So we must adopt the solution for big data. Hadoop is a software platform that can distributed process massive data[11], which implements the MapReduce programming model and HDFS distributed storage architecture. Hadoop has the features of integrating computing and storage resource, scalable storage of massive heterogeneous data, data parallel computing, so it is ideal for electric vehicle charging big data processing.

3.2. Hadoop Based Multi-Level Feedback Queue Optimization Charge Model System Architecture and Platform Building

Hadoop based multi-level feedback queue optimization charge model system architecture is as Figure 4 shown.

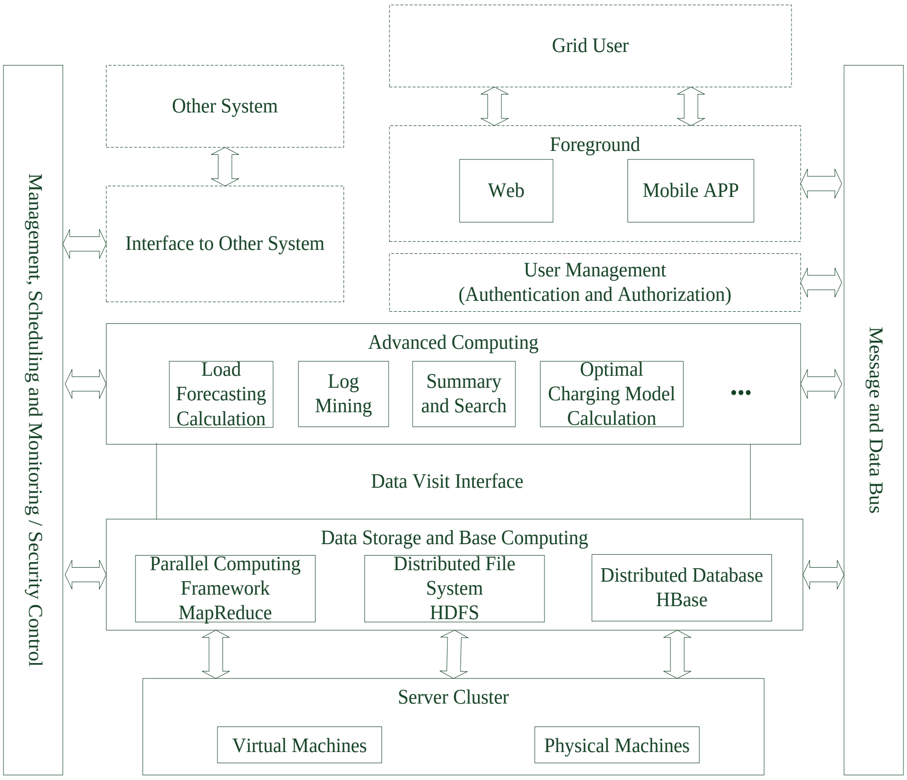

Figure 4. Multi-Level Feedback Queue Optimized Charging System Architecture

On logic, system is divided into physical layer, data storage and calculation layer, advanced calculation layer, data displaying layer, management and control layer, data bus and related visit interface.

Physical layer is the base layer of the system, which include server cluster, virtual machine cluster achieved by virtualization technology, each interconnected line and mobile network.

Data storage and calculation layer uses Hadoop technology to integrate and package the server cluster in physical layer and form a unified platform include distributed file system HDFS, distributed database system HBase and parallel computing framework MapReduce [12]. The imported and collected data will be stored in HDFS and HBase, and some basic computing tasks such as charging optimization goals, will also use MapReduce to parallel prepare and cure to this layer.

Advanced calculation layer is deployed above data storage and base computing layer, which implements some advanced computing functions of system include calculation of multi-level feedback queue optimized model, charging events summary and search, log mining and so on. Advanced computing module obtains data in HDFS and HBase via message and data bus, calls base computing module via the interface low layer offered, and implements advanced calculation function. For example, it calls charge optimization goal calculation module to implement multi-level feedback queue charging optimization model advanced calculation function.

Data display layer offers the user interface to implement Web display function, include web browser and mobile App displays.

Management and control layer is responsible for scheduling and control among the layers, and implements task load balancing, security control, system performance monitoring, and other functions.

Message and data bus provides a way to message data transmission among the layers. So we should develop unified bus to ease the coupling between various levels, which is conducive to the expansion and maintenance of the platform.

The platform hardware and software environment configuration is as shown in Table 1.

Table 1. Platform of Software and Hardware

Node Type	Hardware Configuration	Systrem Configuration
Namenode*1	core-i5 3230;4G RAM	Ubuntu12.04
Datanode*5	Pentium4 2.8GHZ;1G RAM	Redhat5.4

3.3. HBase Based Distributed Storage Structure

In order to facilitate the storage of big data and support Hadoop cloud platform to data process, the structure is designed to distributed database HBase for data persistence. According to non-relational and good scalability of HBase, I designed the database into two large tables, computing base data table and charging request and event table. Computing base data table mainly records various data in grid side, include charging station information, charging pile information, various types of batteries curve, grid background load curve, *etc.* Charging request and event table mainly records users' request and charging information.

Each table structure consists of several row keys and column families, and each column family includes several columns. Table 2 and 3 are the base structure of the above two tables.

Table 2. Structure of Calculation Basic Data Table

Row Key	Column Family
StationID	BasicInfo
	PostState
	BatteryInfo
	LoadInfo
	PriceInfo

Table 3. Structure of Charge Request and Event Table

Row Key	Column Family
EventID	BasicInfo
	PostState
	BatteryInfo

3.4. MapReduce Based Model Parallel Algorithm Implement

Multi-level feedback queue charging model M-R algorithm is divided into Map stage and Reduce stage in accordance with MapReduce mechanism. Map function and Reduce function are designed based on the framework interface [13]. Model uses Map to compute the priority of each task, and uses Reduce to merge and sort priority and divide the tasks into multiple queues. The algorithm contains a secondary sorting process, which sort the charging tasks with priority so that the task into Reducer is already sorted. By this mechanism, the efficiency can be guaranteed. The implementation process of the model is shown as Table 4, 5, 6.

Table 4. Map Procedure of Multilevel Feedback Queue Optimal Charging Model

Class: class MultiQueueMapper extends TableMapper
Function: map(key1,value1,key2,value2)
Input: key1: *stationID; eventID* value1: *tCharge; tWait; tOut*
Output: key2: *stationID* value2: *eventID; Priority*
Process: 1. Obtain and resolve the input parameters from HBase: *key1, value1* 2. Obtain current time into *tCurrent* 3. Call *alPriority()* function, use Formula1-4to calculate task priority into *Priority* 4. Set *key2= stationID, value2= eventID + Priority* 5. Output *<key2,value2>*

Table 5. Reduce Procedure of Multilevel Feedback Queue Optimal Charging Model

Class : class MinLoadReducer extends Reducer
Function: reduce(key1,values,key2,value)
Input: key1: *stationID* values:*List< eventID ; Priority>*
Output: key2:*stationID* value: *List<List< Priority >>>*
Process: 1. Resolve *key1*and *values* 2. Call *divQueue(values)* function to divide priority queue, return a List 3. Set *key2=stationID, value= List< eventID ; Priority>* 4. Output *<key2,value>*

Table 6. Secondary Sort Procedure of Multilevel Feedback Queue Optimal Charging Model

Class: class PrioComparator extends WritableComparator
Function : compare(WritableComparable w1, WritableComparable w2)
Input: w1, w2: Two elements to be compared in sorting, internal structure is: eventID ; Priority
Output: cmp: Comparison results of the two
Process: 1. Resolve *eventID ; Priority* from Element *w1,w2* 2. Set *cmp = Priority1 –Priority2* 3. Return *cmp*

4. Summary and Outlook

This paper introduces the implementation of a Hadoop cloud computing platform based electric vehicle multilevel feedback queue optimization charging model, which presents an electric vehicle optimization charging scheme and uses M-R framework to implement the scheme's parallel computing. It solves a series of electrical problems and is related to big data analysis problems caused by large-scale electric vehicles connected to the grid, and also has reference value for other smart grid optimization problem.

In the Energy Internet, electric vehicle is a typical load and power source. Optimization charging theory combine with energy automatic demand response in regional power grid is a direction for future research. With the gradually improvement of the degree of information fusion and interaction among electric vehicles, charging stations and power grid, private charge position rental service, V2G mode, and other electric vehicles multi information fusion applications will be widely used.

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