Development of Configuration Software of Space Environment Simulator Control System Based on Linux

Zhan Haiyang, Zhang Lei, Ning Juan

Abstract—This paper presents a configuration software solution in Linux, which is used for the control of space environment simulator. After introducing the structure and basic principle, it is said that the developing of QT software frame and the dynamic data exchanging between PLC and computer. The OPC driver in Linux is also developed. This driver realizes many-to-many communication between hardware devices and SCADA software. Moreover, an algorithm named "Scan PRI" is put forward. This algorithm is much more optimizable and efficient compared with "Scan in sequence" in Windows. This software has been used in practical project. It has a good control effect and can achieve the expected goal.

Keywords—Linux OS, configuration software, OPC server driver, MYSQL database.

I. INTRODUCTION

AT present, most configuration software of space environment simulator is developed based on the Windows operating system. With the continuous development of Linux operating system, single situation has been changed only based on the Windows operating system. Linux system itself has very strong functional characteristics: (1) Security. Linux system ensures the security of the system by setting the file permissions. It has a reliable memory management system, improved thread management, and process communication and concurrency control mechanism. Its robustness is stronger than most of the commercial operating systems. (2) Real-time. The real-time of Windows operating system is not as good as Linux. The kernel of Linux is small. The efficiency of Linux is higher. (3) Open source. Linux has an open source code. It is not a black box. Windows is not open. (4) Flexibility. Linux allows users to transform its kernel. It can be customized. The flexibility of Linux is higher than that of Windows. (5) Network functions. Linux has a strong network communication function. The configuration of the network protocol is more flexible. In contrast, Windows's support for the protocol is still relatively limited. (6) Low-cost. Due to the open source, the price of Linux is very competitive. Although the current users between Linux and Windows are still wide apart, the strong performance of Linux has been received developers' recognition. In the field system is a worth thorough research and study of problem. It is the developing

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trends on multi-platform support of configuration software [1], [2].

The control system of space environment simulator integrates data communication technology, database technology, graphics processing technology and automatic control technology. It provides operation process visualization, data collection and data monitoring. It can help users to monitor and control the equipment in real time. It can optimize the production of equipment and the management of resources [3]. Master computer, PLC and printer in the system form a control network through the switch. It is shown in Fig. 1.

II. ARCHITECTURE OF CONFIGURATION SOFTWARE BASED ON LINUX

A. The Architecture of Control System

The configuration software based on Linux receives data from PLC. The protocol is TCP/IP. It reads and writes data through the switch. In order to communicate with the equipment and collect data [4], it is developed a set of PLC driver for the Siemens S7-300 PLC in the Linux operating system. The collected data is put into the process database. The process database is the key in the development of Linux configuration software. It is a transfer program independent developed on Linux to exchange data with the device independent. Relational database MYSQL is responsible for the storage of historical data and alarm information. MYSQL needs to get data from the process database. Software interface uses the QT platform, SVG interface development software and HTML for development. The block diagram of the control system is shown in Fig. 2.

B. The Software Data Flow

The system can be divided into three layers according to the data flow of the software. They are data access layer, data processing layer, and data display layer. Data access layer is to communicate with the field equipment and PLC to complete the data collection. Data processing layer is to calculate, alarm, and store the collected data and to provide the access interface. Data display layer is to display and output data and information and to provide interactive interface [5]. The data flow diagram is shown in Fig. 3.

Process database is the core of configuration software based on Linux. Its development is divided into five parts: (1) It is to realize the function of procedure library through service procedures of background database. (2) It is to establish driver interfaces of database, such as SIM, etc. (3) It is to create,

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modify and browse data through database interface editor. (4) It is to achieve AI, AO, DI, and DO through the establishment of the database block. (5) It is to access database through the establishment of the database access interface.

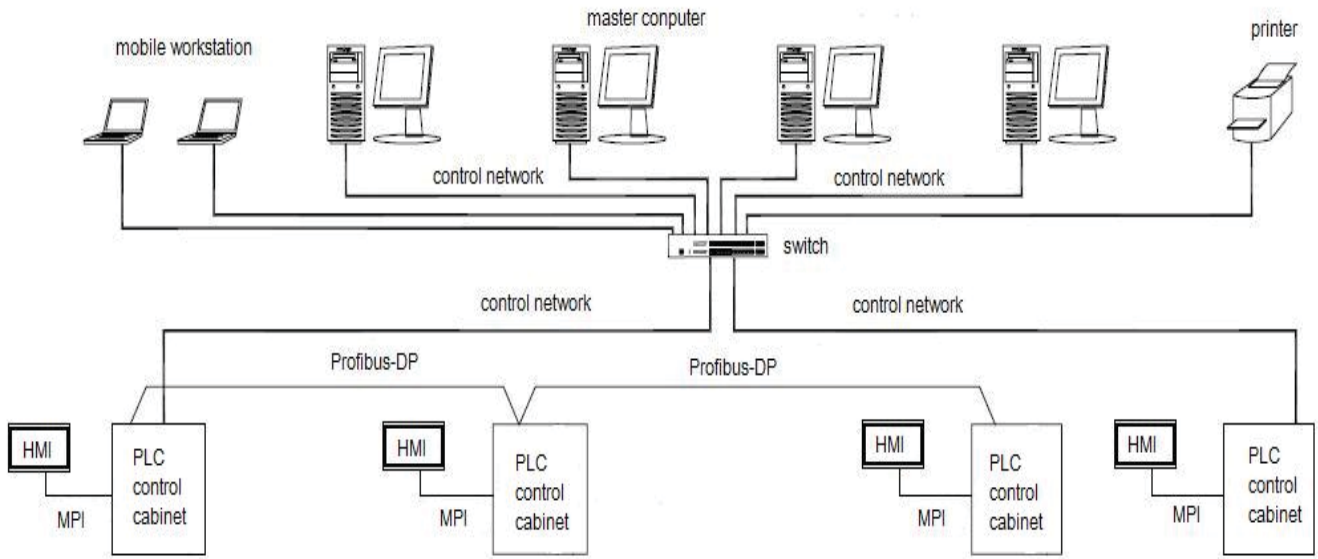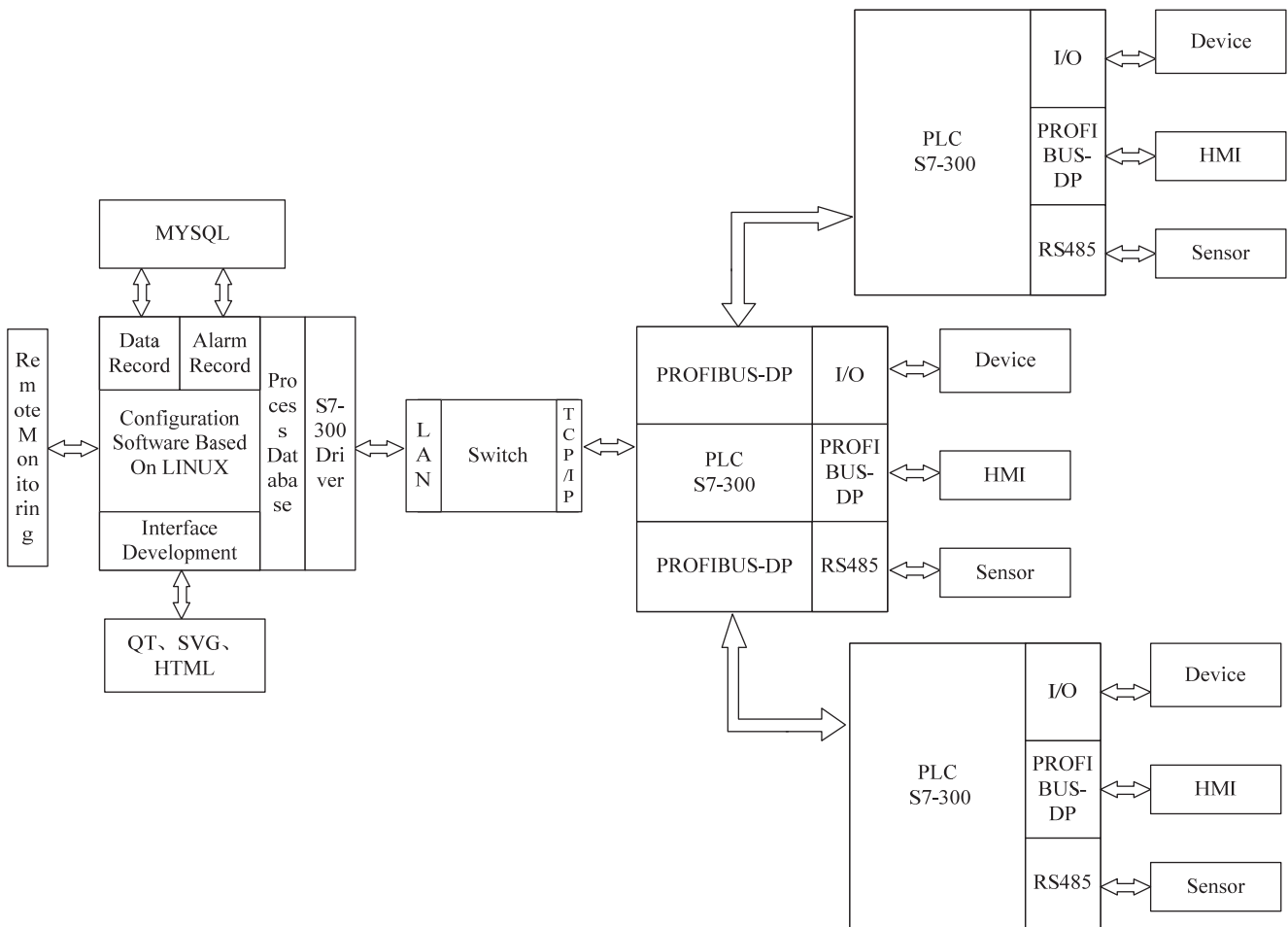Fig. 1 The overall diagram of the control system

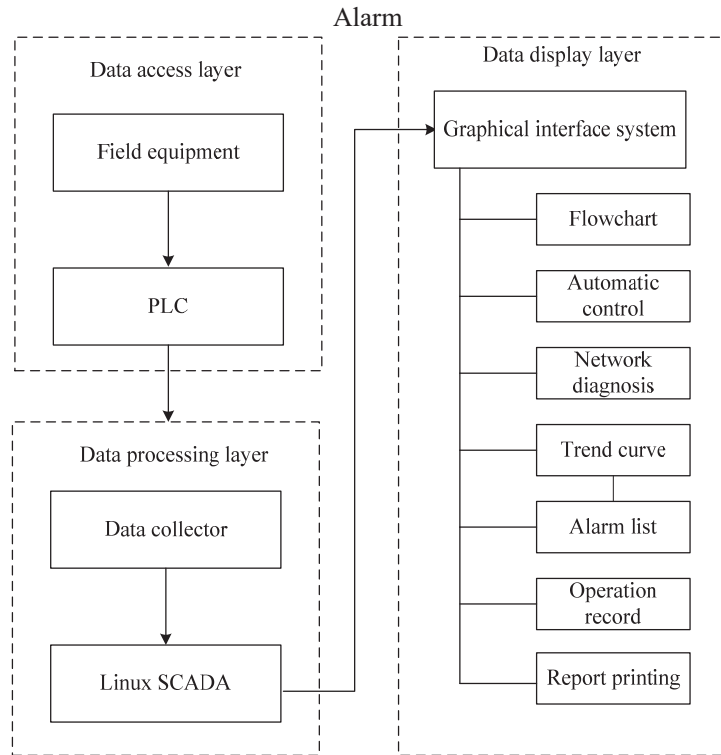Fig. 2 The block diagram of the control system

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Alarm

Data access layer

Field equipment

PLC

Data processing layer

Data collector

Linux SCADA

Data display layer

Graphical interface system

Flowchart

Automatic control

Network diagnosis

Trend curve

Alarm list

Operation record

Report printing

Fig. 3 The data flow diagram

data display layer

Alarm Module

flowchart

automatic control

report printing

trend curve

operation record

data processing layer

Alarm Service

Historical Data Service

Alarm Database

Process Database

Historical Database

Ethernet Data Collector

Ethernet Data Collector

Serial Port Data Collector

data access layer

PLC

PLC
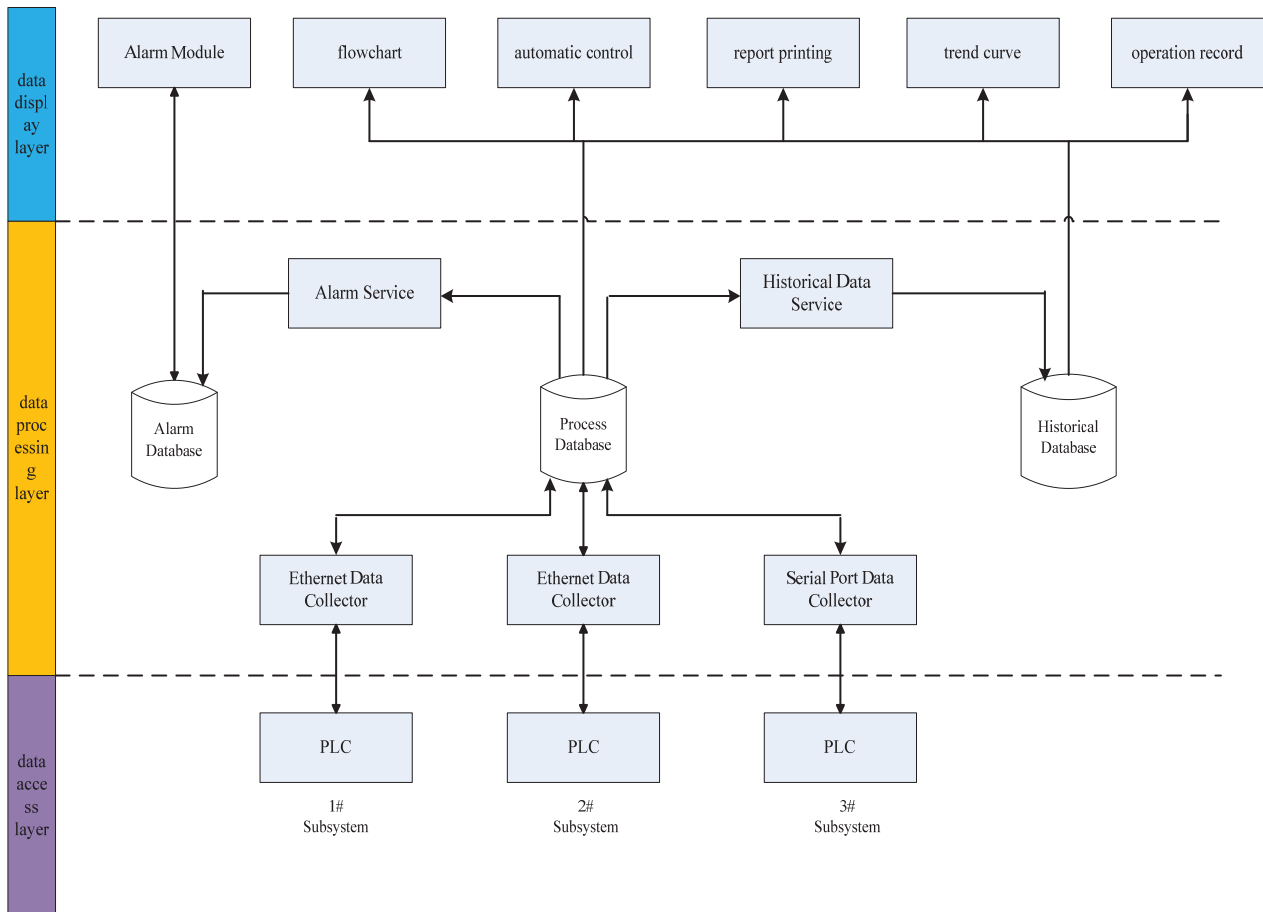
PLC

1# Subsystem

2# Subsystem

3# Subsystem

Fig. 4 The modular diagram of software function

The process database as the core transmits data between alarm database and historical database in data processing layer. It is to realize alarm service and historical data service. The function interfaces of data display layer, such as flowchart, automatic control, trend curve, operation record and report printing, get data from the process database and historical database. It is bidirectional data interaction between the alarm module and the alarm database. Data access layer is made up of PLC. Process database send or receive data from the PLC of each subsystem through the Ethernet data collector or serial port data collector. It is to realize data transmission between data access layer and data processing layer. It is shown in Fig. 4.

III. SOFTWARE ARCHITECTURE AND INTERFACE IMPLEMENTATION

A. The Software Development Environment

The software platform used in the development is Hat Enterprise Linux Red. The development and debugging environment of software architecture is QT Creator. SVG (Scalable Vector Graphics) development environment is for the development of the main process interface. The relational database MYSQL is for the development of the historical database. Use different software platforms as the development and running environment (see Table I).

TABLE I
THE DEVELOPMENT AND RUNNING ENVIRONMENT

Name	Software platform
Development language	C/C++、QT 、Java、html
Development platform	QT4.6
Development and debugging environment	QT Creator 1.3.0
Graphical interface	SVG（Scalable Vector Graphics）
Running platform	Red Hat Enterprise Linux
Database	MYSQL

B. The Software Architecture Based on QT

QT developed by Norway Trolltech Company is a cross-platform C++ graphical user interface application frame. It supports software development in Windows, Linux, UNIX and other operating systems. Its unique signals and slots mechanism is instead of the traditional callback mechanism. The event definition and response of QT are very convenient. Interactive features are easy to achieve. The program is easy to understand and maintain [6], [7]. With the advantage of QT outstanding cross-platform capability, its powerful interface design function has been reflected in the Linux operating system. This project uses the QT platform to build the overall software framework and develop the interface. The development and debugging environment is QT Creator. QT Creator is a visual programming interface design tool. It is very intuitive and convenient to use it to design the program interface. First of all, it is the design of the menu and form. Using UIC（User Interface Compiler） converts .ui file of interface design into c++ header files and source files. After the completion of the interface architecture design, it is to achieve specific functions through the performance function.

The software frameworks based on QT platform are shown in Fig. 5.

C. Interface Development Based on SVG

SVG (Scalable Vector Graphics) development environment is for the development of the main process interface. SVG is a scalable vector graphics. It is a kind of language used to describe two-dimensional graphics and the application of XML. SVG has a significant advantage in addition to the compatibility of multi system platforms. Its image size is not limited to the fixed size. It can be upgraded to different display resolution. It is to enlarge a SVG image for more details. And, the same SVG content can be independent image, can also be referenced to a page, and can also be embedded into the other SVG image. Therefore, a complex SVG image can include many parts and can be completed by a lot of people [8]. This is very important for a complex project that needs to be developed by a team. In the case of the project, it is the need for large-scale system interface design and remote development at home and abroad. With the powerful drawing function and code editing function in SVG Developer, a high quality SVG vector graphics is drawn.

D. Data Management Based on MYSQL

MYSQL is a real multi-user and multi-thread SQL database server. It is a distributed database management system with client / server architecture. It supports Windows, UNIX and other operating systems. Compared with other commercial databases, the usage and maintenance costs of MYSQL are extremely low. For open source database, users can get free authorization. For other commercial databases, the users need to pay the licensing fee per copy or per CPU. At the same time, MYSQL is also the most simple database system. The installation is easy. The management is easy. And the stability of the database is good [9]. Because MYSQL has very good adaptability to the Linux operating system, this project uses MYSQL to develop the historical database and the alarm database.

The development processes of MYSQL are as follows. (1) To establish a database connection. (2) To start the MYSQL server. (3) To enter to create and edit environment in the database. (4) To connect to the corresponding configuration. (5) To use API to develop the database application.

The processes of database programming and data access are as follows. (1) To find the location of data storage and to connect. (2) To request information from a data source. (3) To process the acquired information. (4) To return the processed data to the data source for storage. (5) To disconnect the connection with the data source after the completion of the work.

The following takes the historical database as an example to describe the development process. Historical database uses relational database MYSQL. The historical database gets the data from the process database and archives data. Its development is divided into six parts. (1) To configure the history definition program and to manage history tag name. (2) To realize collection and processing of historical data through

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historical collection program. (3) To view the historical data through historical view program. (4) To provide inquiry and calculation of historical data through historical service program. (5) To develop historical trend control. (6) To configure ODBC.
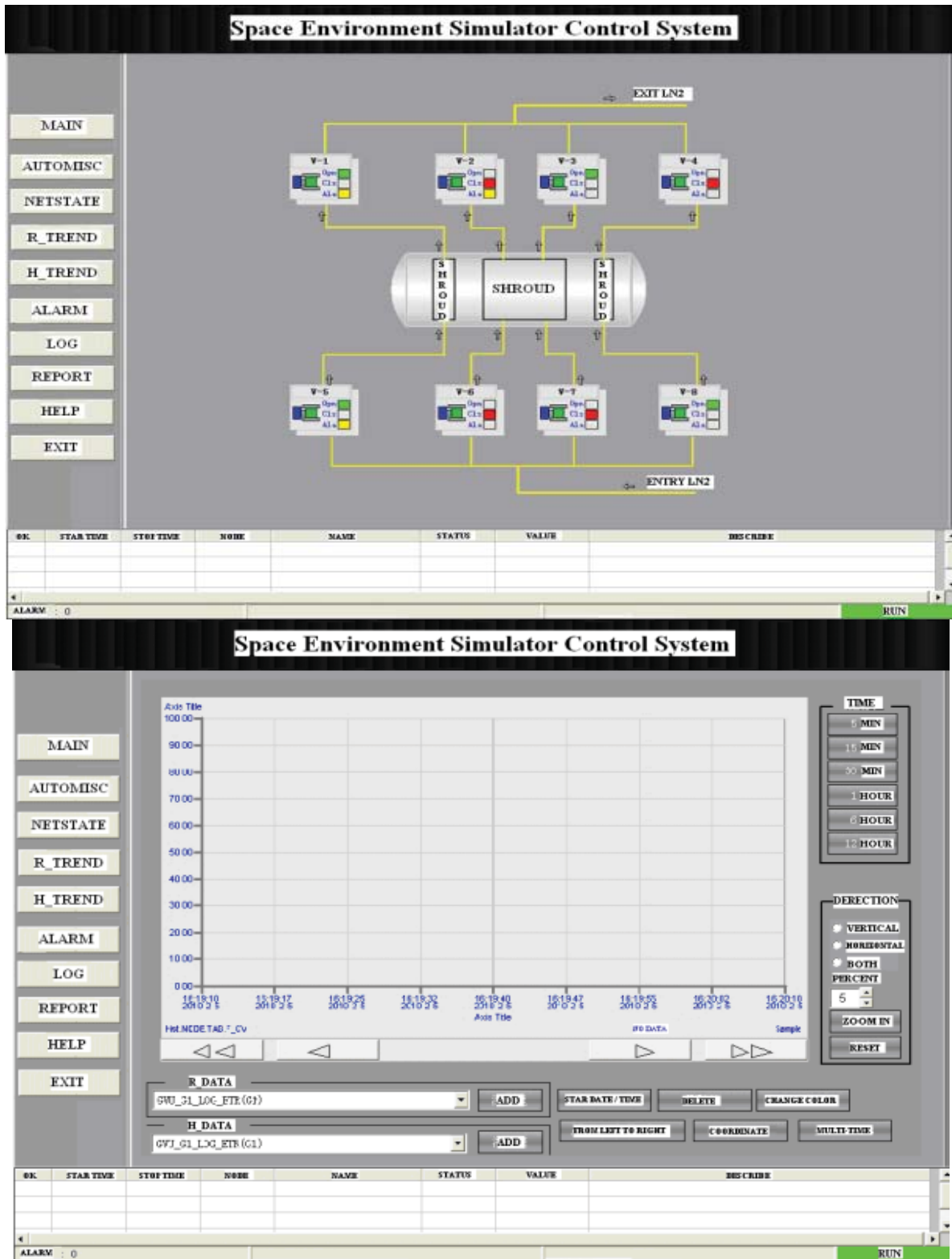

Fig. 5 The software framework based on QT platform

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IV. DEVELOPMENT OF OPC DRIVER BETWEEN COMPUTER AND PLC

OPC is an established and recognized standard for data exchange between control and HMI in manufacturing and process automation. OPC provides a bridge between hardware and software. Through OPC Server interface provided by the hardware vendors, software developers can get the required information from the hardware to achieve remote control [10], [11]. The development of OPC Server based on Windows has been quite mature. But the development of OPC Server based on Linux is not perfect. In this project, a new OPC driver based on Linux system is designed. The communication protection of OPC driver is fully considered. And the design scheme is proposed to control protection under scan priority and time priority.

A. Implementation of OPC Server Driver in Linux System

The bottom controller is used in the SIEMENS S7-300 series PLC. For the SIEMENS S7-300 series PLC a set of OPC Server is developed in Linux. It is to realize the communication between PLC and PC software. The OPC driver supports multiple channels. A channel has multiple devices. One device can build multiple data blocks. It is shown in Fig. 6.
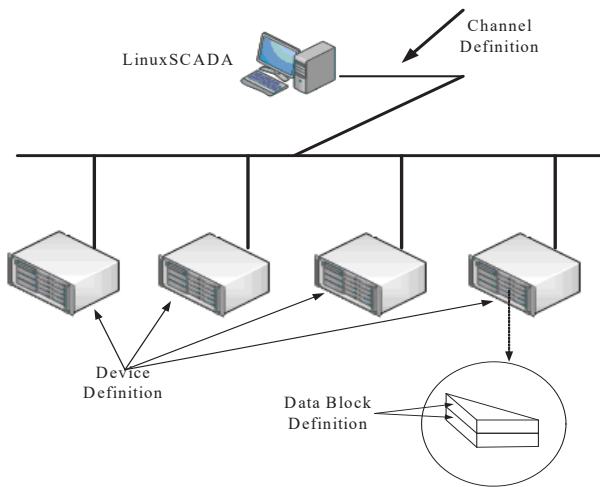

Fig. 6 I/O Drive configuration

OPC Server in Linux need to configure the protocol, channel, device, and data blocks. Use specific configuration parameters (see Table II).

B. Scan Priority Algorithm

In the design of OPC Server scan logic algorithm, this project does not use the commonly sequential scanning method of OPC Server in Windows system, but use a new "scan priority algorithm". This algorithm enhances the reliability of the control protection, and effectively improves the communication control ability between the upper and lower system.

The sequential scanning method of OPC Server in windows system is to refer to scan from first data blocks of first device

from each channel, to scan all the data blocks of the first device sequentially, then to scan second device, until all the devices under channel are scanned. The various channels are the parallel relationship. The device of each channel is scanned in sequence. Sequential scan algorithm is shown in Fig. 7.

TABLE II
OPC SERVER CONFIGURATION PARAMETERS IN LINUX

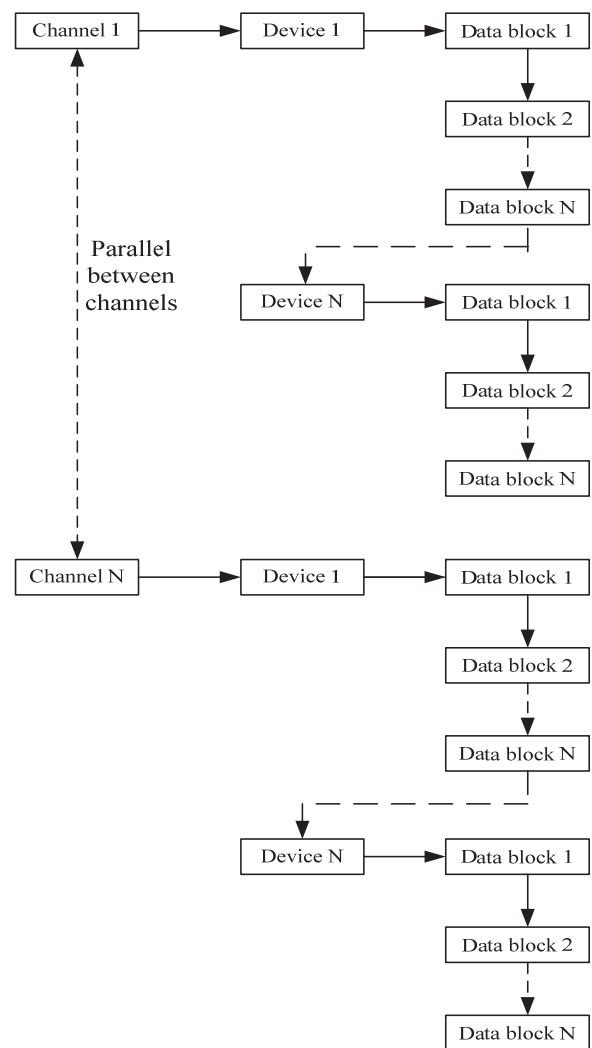| Protocol configuration item	Channel configuration item	Device configuration item	Data block configuration item
Timeout	Channel description enable or disable the channel	Device description	Data block description and types
Maximum error times		Device address	Variable address
Failure time interval	IP address	enable or disable device	Number of tag
Fault repair time interval	Port number	Number of data blocks	Scanning time
Priority time interval	Device name	Data block name	Scan priority
Number of channels			enable or disable data block

Fig. 7 Sequential scan algorithm in windows

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Sequential scan algorithm has drawbacks. If scanning time defined by user is too small, the system cannot scan all the data blocks, and result in a loop scan on a few blocks of data, and have no time to scan other data blocks when the scanning time is up. In order to avoid this problem, the scan priority and priority time interval are introduced in the design of the scan algorithm. Four priorities are defined. Each data block corresponds to one of the four priorities. Data blocks of the same priority form a priority queue. In addition, four variables are defined to record the serial number of the current data block in the queue. Scan from the first data block in the queue with a priority of 1. Check whether there is the control command and the priority time of other queues reach after the completion of the scan. If the priority time of other queues is reached, the current data block of the queue is scanned. If the priority time of other queue is not reached, the scanning time of the current queue is determined to arrive. This scanning time is the interval between the two blocks of the same queue. If the scanning time is reached, the next data block of the current queue will be scanned. If the scanning time does not reach, it is again to determine whether the control command and the priority time of other queues is reached. Scan priority algorithm is shown in Fig. 8.

The scan logic of OPC Server in Linux is as follows: At first, the scanning is based on the data block unit. The basic scanning time is defined as the time interval in the data block. If a communication error occurs, the scanning time interval is a failed time interval. If the maximum number of communication failure occurred is reached, the scanning time interval is the time interval for troubleshooting.

When the maximum number of failure or timeout on reading device is reached, it is as device failure. In this case, the scanning program will set the data status to invalid. And the state of the database will be invalid. When the fault is repaired, the scanning program will change the scanning time interval to the time interval for troubleshooting. Check whether fault is restored once in a while and a series of protective measures were taken during the time of the control. If the data state in the database is not valid, the communication failure occurred and refused to send the control command. If the data is valid, but the value in the database is controlled, it refused to send the control command. Check whether the control command is success after send the control command. If the value is not changed larger than the pre-defined time, it is considered to be control failure. The delay time of the command will be checked when the scanning program is running. If it is timeout, the control command is given up for avoiding error control.

V. Conclusions

This paper presents configuration software of the space environment simulator control system based on the Linux operating system. The design principle and development scheme of the software are introduced in detail. This is the first time that the configuration software of the space environment simulator control system is successfully developed on the Linux operating system. The multi-platform development of the configuration software for space environment simulator is explored in the future. With the rapid development of Linux, the development of the control software based on the Linux operating system for the space environment simulator will become a trend.
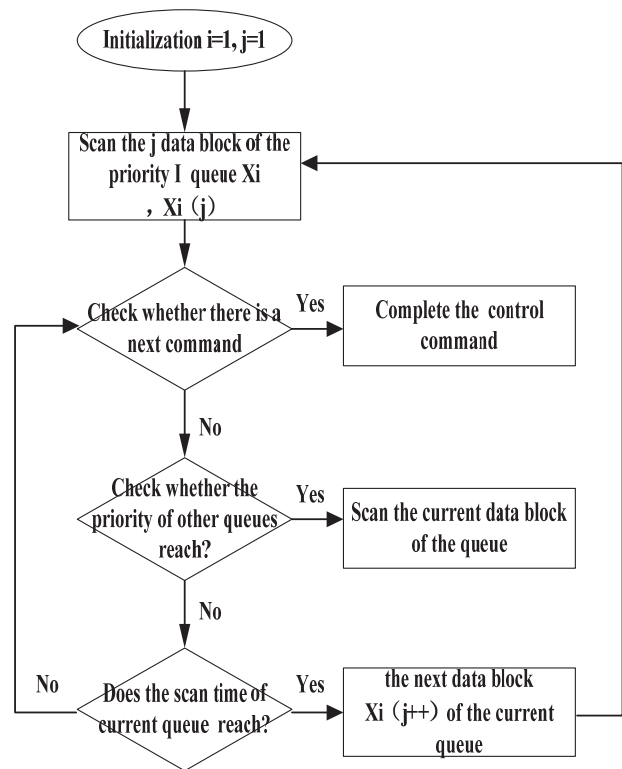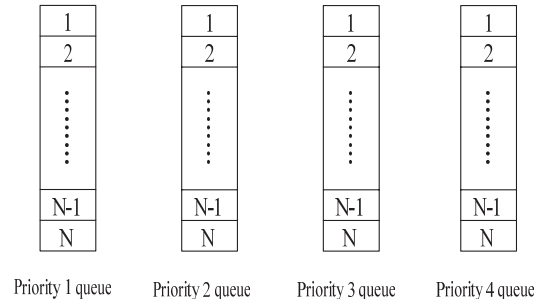

Priority 1 queue   Priority 2 queue   Priority 3 queue   Priority 4 queue

Fig. 8 Scan priority algorithm in Linux

References

[1] Brouce Molay, *Understanding Unix/Linux Programming A Guide to Theory and Practice.* New York: Pearson Education, 2005.
[2] Fang Laihua, Wu Aiguo, He Yi, "Research on the key technology of configuration software," in Control and instruments in chemical industry, vol. 31, pp. 33-36, Jan. 2004.
[3] Zhao Lijun, Pang Hewei, Cui Junfeng, "The design of the level control system for satellite's thermal test platform," in Spacecraft environment engineering, pp. 215-220, Aug. 2006.
[4] Liu Chang, Wang Yirong, "The design of the frame system for the measurement and control software in vacuum thermal tests," in Spacecraft environment engineering, pp. 324-327, Jun. 2010.
[5] Yuan Xiuying, *configuration control technology.* Bei Jing: Publishing House of Electronics Industry, 2003.
[6] Olson, M.A, "Selecting and Implemntineg an Embedded Database

System," in IEEE Computer, vol. 33, pp. 27-34, Sep. 2000.

[7] Liu Zhengrong, *Embedded Linux Development Guide.* Bei Jing: China Machine Press, 2004.

[8] Chen Chuanbo, Wu Fangwen, "A study of description model of graphic element object based on SVG," in Journal of HuaZhong university of science and technology (nature science), vol. 30, pp. 50-52, Oct. 2002

[9] J Stankovie, "Misconceptions about Real-Time Databases," in IEEE Computer, vol. 32, pp. 29-36, Jun. 1999.

[10] Zhu Sanyuan, Qian Weile, Su Weimin, *Introduction to software engineering.* Bei Jing: Science Press, 2002.

[11] Peter H Feiler, *Configuration Management Models in Commercial Environments.* New York: SEI, CMU, 1991.