Design and Implementation of an Elevator Power Failure Warning System

Qiang Huang, Jianmin Cao* and Ruize Sun
College of Big Data and Internet, Shenzhen Technology University, Shenzhen, China
Email: caojianmin@sztu.edu.cn

Abstract. The elevator power failure is a serious safety accident and needs to be detected in time. Therefore, it is essential to monitor this situation via up-to-date technology. A novel warning system is proposed for the accident of the elevator power failure. Firstly, the data collector based on STM32 microcontroller is designed for collecting the elevator operation data from the Controller Area Network (CAN) bus interface of the elevator. Then these data are sent to the remote monitoring platform via the NB-IoT module. The platform extracts various operating signals of the elevator from the CAN bus data, such as door opening and closing signals, internal stroke signals, and stopping operation signals. Therefore, the warning system can further determine whether there is a power outage or the elevator is trapped.

1. Introduction
With the continuous development of urban construction and the increase of high-rise buildings, elevators are widely used in the national economy and life [1]. As the large number of elevators, busy action, frequent failure, and little maintenance personnel, which will bring the personal and property hazards, the elevator’s safe issue has become a common concern [2]. At present, the elevator’s safety guarantee mainly depends on the regular maintenance of the corresponding unit and the regular examination by the elevator inspection agency. With the large number of elevators and the shortage of maintenance managers, how to find elevator failures in a timely manner and take effective measures to deal with them has become a topic that elevator users, supervision departments and maintenance organizations must jointly address [3].

At present, there are mainly two methods of elevator monitoring. One way is to add sensors to the elevator shaft and the elevator car, and monitor the operating status of the elevator through the status of different sensors. For example, a magnetically controlled switch is used to detect the opening and closing state of the elevator door. The human body infrared sensor is used to detect whether someone is in the elevator during operation. Combining the status of the magnetic control switch and the human infrared sensor can determine whether the elevator is trapped [4]. However, this method is complicated to install and high in cost, and there are cases of sensor false alarms. Above all, the failure judgment rate is low. Another method is to obtain the elevator running signal through the protocol conversion board, but this method does not have versatility and extensiveness because the elevator manufacturer needs to announce the elevator protocol [5].

It is proposed a novel warning system, which can monitor whether the elevator has a power outage. The system does not only need to install any sensors, nor does it need to perform protocol conversion. In our warning system, data collector uses advanced STM32 microcontroller. The data collector collects the elevator operation data through the CAN bus [6] interface, and sends the data to the remote monitoring platform through the NB-IoT [7] module. After the elevator is trapped, the warning
system can send out alarm information within one minute and remind maintenance personnel to deal with it as soon as possible, and it has the function of cancelling alarms.

2. System Structure
The structure diagram of elevator power failure warning system is shown in figure 1. The warning system includes three parts: data collector, remote monitoring platform and app client. The data collector locates at the control cabinet of machine room, which is used to collect elevator operation data from the CAN bus interface, and then send the data to a remote monitoring platform. The remote monitoring platform analyzes the elevator data to determine whether a power failure has occurred. If a power failure occurs, the alarm information is sent to the app client of elevator maintenance personnel, then elevator maintenance personnel are reminded to go to repair. If the maintenance staff have completed the troubleshooting, they can apply to revoke the alarm.

Due to the high-rise buildings, the connection method between the elevator controller and the elevator control box generally uses serial transmission, such as the CAN bus interface. The data collector will take out the operating data from the CAN bus interface of the elevator controller and control box (signal processing board). The specific connection diagram of data collector and elevator serial interface is shown in figure 2. The data collector will be linked to the Can+ interface, Can- interface, Volt Current Condenser (Vcc) interface and Gnd interface of the elevator controller.

![Figure 1. The structure diagram of warning system.](image1)

![Figure 2. Connection diagram of data collector and elevator serial interface.](image2)
3. The Design of Data Collector
The function block diagram of data collector is shown in figure 3. The data collector mainly includes seven parts: photoelectric isolation, CAN module, STM32 Microcontroller Unit (MCU), NB-IoT module, charge and discharge management, voltage regulator circuit, and 3.7V battery. We adopt one-way photoelectric isolator to avoid the influence of the data collector on the original elevator system. More often than not, the energy of the data collector is supplied from the elevator power. Once the elevator is powered off, the 3.7V battery is used as the power for the data collector. CAN module is used to receive the elevator operation data.

3.1. STM32 MCU
The main chip of controller for data collector is STM32L433Rx, which is designed by STMicroelectronics (ST) and is a reliable 32-bit processor. Its chip is pin LQFP64 package, using the ARM Cortex-M4 core, with four USARTs and 256K ROM.

3.2. NB-IoT Module
Using NB-IoT to achieve remote monitoring data transmission with low power consumption, wide coverage and low tariff. The NB-IoT module uses BC35-G produced by Quectel. This module is a high-performance, and low-power multi-band NB-IoT wireless communication module that supports B1/B3/B8/B5/B20/B28 Frequency band. Its size is only 2.36 mm*19.9 mm*2.22 mm and it uses AT commands to control it through the serial port. It has a built-in network service protocol stack and can transmit and receive data in multiple ways.

3.3. Charge and Discharge Management
In order to be able to monitor the power failure of the elevator, a power management module must be added to the data collector. The power management module of the data collector is divided into three main parts: the lithium battery charge and discharge power management part, and the power supply voltage stabilization part. The power management module topology is shown in figure 4. The data collector manages 3.7V battery charge and discharge through TP5400 chip. When the battery is charged, the chip steps down the 5V voltage to 3.7V. When the battery is discharged, the chip boosts the 3.7V voltage to 5V. Since the elevator power supply voltage is 24V, it needs to be pulled down to 5v through the LM2576 voltage regulator circuit [9]. Since the operating voltage of the microcontroller (MCU) and NB-IoT module is 3.3V, it is necessary to step down the 5V voltage to 3.3V through the RT8059 voltage regulator circuit.
3.4. CAN Bus Data Preprocessing

Because CAN bus data is too large and contains some meaningless data. We first filter the data according to the data frame ID, and then set a data buffer queue with a size of 8192 bytes to prevent the data from being overwritten before transmitted.

LiteOS is an operating system that provides Unix-like abstractions to wireless sensor networks. LiteOS maps a sensor network into a UNIX-like file system, and supports extremely resource-constrained nodes such as MicaZ. It supports C programming natively, and allows online debugging to locate application bugs [10]. Thus, the data collector uses Huawei Liteos operating system to allocate and schedule resources for the microcontroller.

Finally, the physical effect diagram of the data collector we designed is shown in figure 5. In the experiment, the data collector can not only successfully collect the elevator operation data, but also transmit the elevator operation data to the remote monitoring platform in real time.

4. The Judgment for Elevator Power Failure

The remote monitoring platform can extract internal signals, door closing signals, elevator running signals, elevator stopping signals and other signals from the Can bus data. Then it can be judged whether the elevator is powered off and whether there is a power failure after a power failure based on a logical combination of these signals electric trapped people faults, levelling faults, etc.

The judgment logic of whether the elevator is powered off is shown in figure 6. During the elevator operation, when the elevators stop running signal from the elevator control box is received, the level will change from reset to set (low level to high level) which indicates that the elevator has stopped unexpectedly.

If the can signal is not received within the next 3 seconds, the system will continue to determine whether the elevator has carried passengers signal. If received, it can be judged that the elevator stopped running and trapped people. If there is no passenger signal, it can be judged that the elevator is powered off and stopped.

If the can signal is received within the next 3 seconds, it means that the elevator is powered on again or there is a backup power switch. At this time, the warning system determines whether still receives the elevator stop signal, and if so, continue to determine whether the elevator has carried passengers. If the elevator has carried passengers, it can be judged that the elevator stopped running
and trapped people. If there is no signal from the elevator, it can be judged that the elevator stopped running and leveling fault.

If the can signal is received within the next 3 seconds, but it is not the elevator stop signal, the elevator resumes normal operation. Generally, the elevator opens the door near the flat floor to let people out.

When the remote monitoring platform judges that the elevator stopped running and it is trapped, it issues a corresponding alarm signal. Including audible and visual alarms, SMS, emergency calls, mobile app and other forms to notify elevator maintenance personnel, the alarm signal will not stop until the maintenance personnel respond.

The model of the experimental elevator is Monarch NICE3000, and the installation of the data collector is shown in figure 7. In the experiment, we simulated an elevator power outage accident, the display page of the APP client is shown in figure 8 when the elevator stops running and there are trapped people. When the elevator is out of power but not trapped, the display page of the client is shown in figure 9. When the elevator has a leveling fault, the client display page is shown in figure 10. The experiments have validated the effectiveness of our proposed methods in the accident of the elevator power failure.

![Figure 6. The judgment of elevator power failure.](image)

![Figure 7. The installation of the data collector.](image)
5. Conclusion
The elevator power failure warning system collects elevator operation data from the CAN bus of the elevator, and analyzes and extracts the elevator door open and close signal, internal stroke signal, and stop operation signal from the CAN bus data. The warning system has the following advantages:

• Unified data acquisition interface CAN bus. CAN bus is a serial bus protocol used in most automotive industries, and CAN bus interface is a universal communication interface for elevators. The unified data acquisition interface of CAN bus can provide convenience for centralized monitoring and fault judgment of the elevator.

• High failure judgment rate. The real operating data of the elevator is collected through the CAN bus, which can ensure a high failure judgment rate.

• Low construction and installation costs. Because a large number of sensors are not used to collect elevator fault data, but elevator data is collected at the CAN bus interface of the elevator system, and the data is transmitted through the NB-IoT wireless network. Not only is the construction cost low, but the installation is convenient, which is conducive to the promotion of the system use.

• Just keep it under control. The underlying data acquisition equipment collects data through the CAN bus interface of the elevator system, and uses one-way photoelectric isolation to collect data. The signal will not be fed back into the elevator system and will not affect the operation of the original elevator system, that can eliminate the elevator managers’ concerns about installing elevator monitoring equipment.

The safety of the elevator use is closely related to the safety of residents’ lives and property. The elevator power failure warning system proposed in this article can improve the safe operation level and service level of elevators, which has an important social significance.

Acknowledgments
First of all, the successful completion of this thesis is inseparable from the care and help of teachers, classmates and friends. I would like to thank Dr. Lei Ning for his guidance on hardware and Dr. Mingchuan Yuan for his guidance on software programming. We also thanked En Quan and Qijun Hong for their help. At the same time, we also want to thank the Guangri Elevator Industry Co., Ltd for providing the experimental elevator, which helped us with the experiment. Finally, I sincerely thank the experts and teachers who took the time to review this thesis. Due to my limited level of
knowledge and writing, it is inevitable that there are omissions in the writing of this article. I urge experts and teachers to criticize and correct them.

References

[1] Wang F, Zhu J and Xie D 2012 The elevator upgraded the application research 2012 IEEE 11th International Conference on Cognitive Informatics and Cognitive Computing pp 444-447.

[2] Lia S, Hub H and Jin Y 2014 Design and implementation of elevator monitoring terminal Advanced Materials Research 926-930 1253-1255.

[3] Li Y, Jiang Y and Wu F 2019 Design of elevator monitoring system based on IOT Machine Building & Automation 48 212-215.

[4] Shi H and Pu H 2018 Intelligent elevator control and safety monitoring system Automation & Instrumentation 33 105-108.

[5] Chen J, Li X, Zhang S, Li L, Yang H and Wang X 2018 Remote monitoring system of elevator energy consumption in green building based on ARM Modern Manufacturing Engineering 9 6-10.

[6] Salunkhe A A, Kamble P P and Jadhav R 2016 Design and implementation of CAN bus protocol for monitoring vehicle parameters 2016 IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT) pp 301-304.

[7] Sun R, Chang W, Talarico S, Niu H and Yang H 2019 Design and performance of unlicensed NB-IoT 2019 16th International Symposium on Wireless Communication Systems (ISWCS) pp 469-473.

[8] STMicroelectronics Group of Companies 2017 Functional Overview STM32L431 Datasheet pp 50-51.

[9] Lou Y, Gao S, Jia M and Cao F 2011 Research and design of new home solar charge-discharge system 2011 Second International Conference on Mechanic Automation and Control Engineering pp 6724-6727.

[10] Cao Q, Abdelzaher T, Stankovic J and He T 2008 The LiteOS operating system: towards UNIX-like abstractions for wireless sensor networks 2008 International Conference on Information Processing in Sensor Networks (IPSN 2008) pp 233-244.