GPP-SDR Based GSM-R Air Interface Monitoring System and Its Big Data Interference Analysis

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Abstract. In the railway transportation industry, the monitoring of Global System for Mobile Communications for Railway (GSM-R) network is essential, which plays an important role in safety of the train. The traditional monitoring systems are mainly based on the A/Abis or PRI interfaces. Therefore, the traditional ways are difficult to monitor random interferences and faults occurred over wireless channels, which may causes the potential security menace. In this paper, we propose a GSM-R monitoring system based on the Um interface. Adopting the General Purpose Processor (GPP)-Software Defined Radio (SDR) framework, the GSM-R network can be monitored by full Um interface information, including spectrum, signaling and traffic information. We use the GPP-SDR based front-end processors to obtain the data from Um interface, which are transmitted to the center servers in a railway bureau data center. After receiving the original data, the C/S structure based center servers will process the data for users to monitor. The whole system design has been implemented and deployed in Guangzhou Railway Bureau, including Guang-Shen Line and Guang-Shen-Gang Line. Furthermore, a big data interference analysis framework is proposed based on the Um interface monitoring database, which has also been verified to successfully capture and classify traditional types of interferences in field tests.

Keywords: GSM-R monitoring · GPP-SDR framework · Big data analysis
C/S structure

1 Introduction

With the continuous promotion and development of high-speed railway, the Global System for Mobile Communications for Railway (GSM-R), as the transmission channel of automatic train control and detection information, is becoming more and more important and has been widely applied in railway operation around the world [1]. Since the International Union of Rail Ways (UIC) puts forward the system in 1992, the GSM-R developing into the most mature and widely used wireless communication system specially developed for railway application after more than 20 years of development.

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Since the GSM-R wireless communication system is carrying the important train control data, the safety and reliability of the GSM-R system will directly affect the security of the train operation. When the interferences occur, the train operation scheduling will face serious risk. If someone launches the radio interference signal in the GSM-R band, it will seriously affect the normal receiving and launching of the railway signal, which will not only lead to the decrease of railway operation efficiency, but also bring considerable hidden danger to railway safety operation, the personal safety of passengers and even national stability. Therefore, the GSM-R monitoring system, which can effectively monitor the signal and interference in the GSM-R network and analyze the useful signals in the GSM-R network under the condition of eliminating the interference, plays a vital role [2].

Because of the importance of the GSM-R monitoring system, how to better set up it has aroused wide attention. At present, the GSM-R monitoring system in China is mainly composed of some subsystems such as A interface monitoring, Abis interface monitoring, PRI interface monitoring and other managed and comprehensive analysis systems [3]. The locations of the different interfaces in the GSM-R system are shown as Fig. 1. This monitoring system has played an important role in the GSM-R wireless network optimization in China. Besides, it is becoming more and more accurate for the analysis of interference and failure. However, this system also has its insufficient aspects. When the interference and failure occur in the wireless channel between the MS (Mobile Station) and BTS (Base Transceiver Station), the existing means are difficult to find out the reasons.

As we know, the wireless channel is very fragile. Besides, at present, we are lack of wireless channel monitoring data. Therefore, it is still helpless for us to deal with some difficult faults, and the more accurate GSM-R monitoring system which can also monitor the wireless channel is becoming more and more urgent.

The traditional way to monitor the wireless channel is to test the channel along the railway by using a test cellphone or an instrument with an analytical function. However, the manual ways not only waste manpower, but also cannot continue to monitor the wireless channel. Accordingly, we propose a GSM-R monitoring method based on the GPP-SDR (GPP: General Purpose Processor, SDR: Software Defined Radio) framework which mainly uses the data from the Um interface usually called air interface. Based on this method, we have implemented the monitoring system through the combination of hardware and software, and we finally apply it to the actual project which can help us to monitor the GSM-R system automatically.

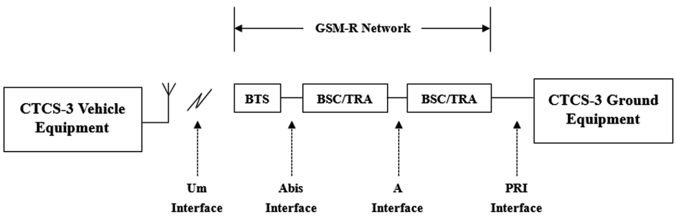

Fig. 1. The locations of the different interfaces in the GSM-R system

The structure of the paper is as follows: Sect. 2 describes the framework of our monitoring system; Sect. 3 provides the implementation method of our hardware and software platform; Sect. 4 introduces the application of our system; and Sect. 5 summarizes the paper.

2 The Framework of Our Monitoring System

In order to monitor the GSM-R network more intelligently, we have set up the monitoring system based on the GPP-SDR framework and big data analysis. Besides, we have further divided the servers by different functions.

2.1 The GPP-SDR Framework and Big Data Interference Analysis

Proposed in 1992, the Software Defined Radio (SDR) is radio broadcast communication technology [4]. Its wireless communication protocol is implemented by the software definition rather than the connection between the hardware which has made it more flexible for the wireless communication system to update itself. Besides, the SDR also brings many other benefits to us, such as reducing the space of the system and decreasing the cost. Different SDR devices may have different structures, however they are usually connected to the General Purpose Processor (GPP) which help to control the SDR devices [5]. With the continuous development of science and technology, the server has made great progress which makes it possible for the server to handle big data analysis just like the large railway data.

With the support of current science and technology, we propose a GSM-R monitoring system based on the GPP-SDR framework and big data analysis, as shown in Fig. 2. At the beginning, the front-end processor which communicates with the computer will collect the interface signaling, user service data and spectrum data from the Um interface through the control of the software rather than the connection of the hardware. Secondly all kinds of data will be transformed into JavaScript Object Notation (JSON) files and then transmitted to the server via Ethernet. Finally the server will carried out further parsing, processing and providing to users with the received data, so as to monitor the GSM-R system. In our system, a server can receive data from multiple front-end processors and processes them simultaneously.

2.2 The Data Server Structure

For the server, we use a hierarchical design architecture according to different functions, as shown in Fig. 3. In this structure, the DB-Servers only write the original data into the database and write the database two times after simple parsing. Besides, other big data analysis and query applications are distributed on the application servers (App-Servers) which obtain the data from DB-Server via the local area networks (LAN). The applications have their own databases on the application servers which store the data that the user needs. Therefore, the user can monitor the GSM-R system by observing the analysis results of different clients on the App-Server.

In order to make our system more robust and make it more convenient to update, we will further develop the Browser-Server (B/S) structure on the basis of the exiting Client-Server framework.

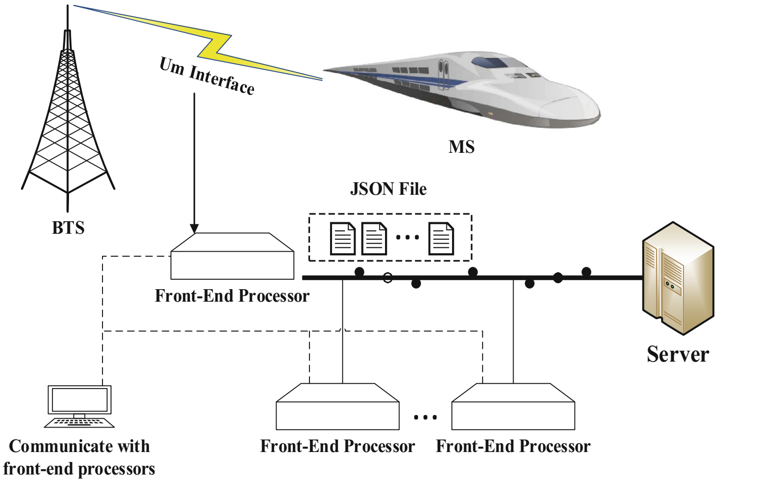

Fig. 2. The framework of the monitoring system

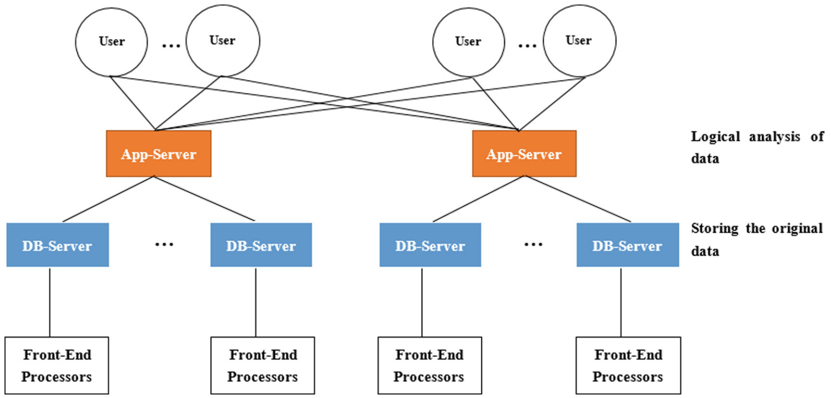

Fig. 3. The structure of the server

3 Hardware and Software Platform Implementation

In order to apply our system to the practical projects, we need hardware and software to realize our ideas. At present, we have implemented the framework mentioned above and applied it to some Chinese railways as the GSM-R monitoring system.

3.1 Hardware Implementation

The main hardware parts of out monitoring system are composed of the front-end processors and the servers. As shown in Fig. 3, multiple front-end processors will be connected with a DB-Server via Ethernet. Besides, the App-Server and DB-Server will communicate with each other through LAN.

The front-end processors mainly monitor the Um interface continuously and translate the received data into JSON file which will be transmitted to the DB-Server. The value of the monitoring frequency or other parameters can be modified by sending commands to the front-end professors from the host computers.

To monitor the GSM-R network, we need servers to analyze and deal with a large number of railway data obtained from the front-end processors. As shown in Fig. 3, different servers implement different functions. For example, the DB-Servers mainly simply process and store the original data. In addition, the App-Servers make logical analysis of data obtained from the databases in DB-Server.

3.2 Software Implementation

With the support of the above hardware, we have developed some software to handle and analyze the big data of the railway, so as to realize the monitoring of the GSM-R system.

(A) **Database Design**

Considering that we are going to deal with a large amount of data, we have designed the day table for the databases, which has a larger increase in the query speed compared with the month table. Besides, we use the MySQL as our databases management system.

In the database operation, we use the method which writes twice to the database to process original data, as shown in Fig. 4. At the first time, the spectrum data and signaling data will be separately inserted into spectrum databases and signaling databases after simple analysis. Afterwards, the signaling data will be decoded by the decoding program according to the protocols, which is multithreaded operation. After decoding, the decoded data will be reinserted into the signaling databases, which includes a lot of information for monitoring the GSM-R system.

(B) **Intelligent Interference Analysis Software**

For the purpose of monitoring the GSM-R system automatically, apart from the databases, we also need the intelligent interference analysis software. In our monitoring system, we mainly monitor the interference on the wireless channel via the intelligent interference analysis software. The implementation of the software is based on the big data obtained from the spectrum databases and signaling databases.

Since the spectrum data contains the amplitude values of different channels at different times in the GSM-R system which can directly reflect the work of the wireless channel, we have designed our intelligent interference analysis software mainly based on the big spectrum data and part of the signaling data, as shown in Fig. 5. In Fig. 5, the interference module mainly works as Fig. 6.

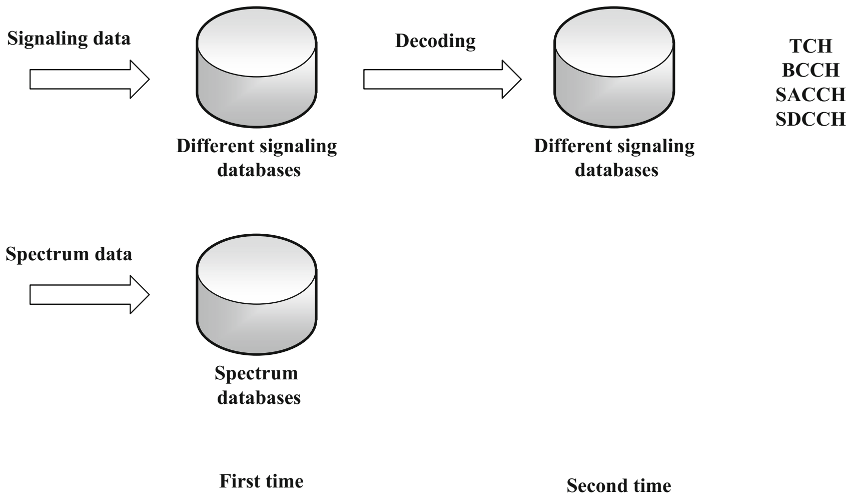

Fig. 4. The operation of the databases

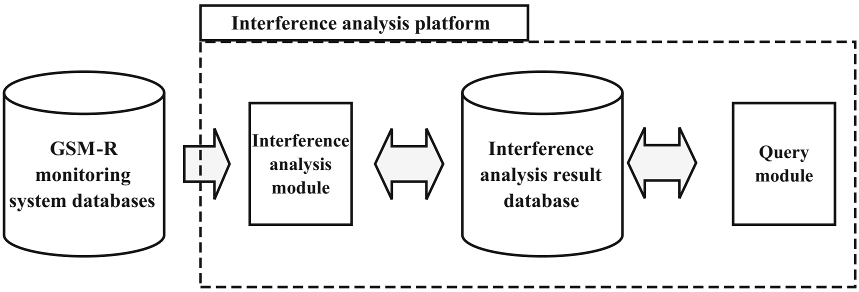

Fig. 5. The interference analysis platform

When analyzing the data of each front-end processor, we will firstly build a model based on the spectrum data selected from several days. Afterwards, we will automatically analyze the spectrum data based on the model and the signaling data every half an hour. The user can access the analysis data and restart the analysis when they need. The algorithm of processing a front-end processor is shown in Algorithm 1.

At present, machine learning has been developing rapidly and is applied in many fields. For our intelligent interference analysis system, we are going to take a machine learning approach, such as the decision tree algorithms, to optimize our methods to make the GSM-R monitoring more accurate.

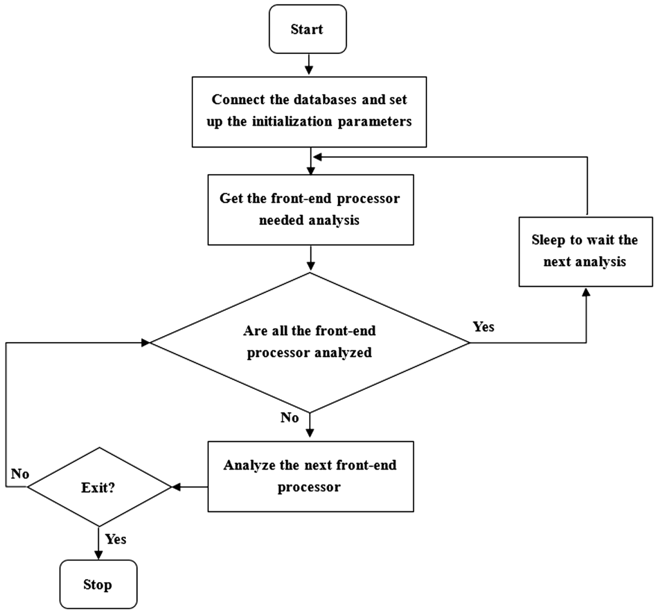

Fig. 6. The interference analysis module

Algorithm 1 Analyze the front-end processor

Get the begin time $\mathbf{T_1}$ and the end time $\mathbf{T_2}$.
Start with the processing time $\mathbf{t} = \mathbf{T_1}$, **segment** = 30s.
if not stop analysis **do**
  for $t < T_2$ **do**
    1. Spectrum data processing:
    Analyze the spectrum data based on the model values and measurement report.
    if have interference **do**
      Insert the information of the interference into the interfering databases
    end
    2. Sweep frequency data processing:
    Analyze if there are interferences by using the sweep frequency data.
    if have interference outside the GSM-R system **do**
      Insert the information of the interference into the interfering databases
    end if
    t = t + segment
  end for
end if

(C) **Other Software**

Apart from the above software, we have also developed many other supporting software. We have developed the network management software to manage and control the front-end processor which can help us monitor the processor and improve the reliability of the system. Besides, we can query the decoding information of spectrum, signaling and business in the independent client, which is mainly based on the signaling databases.

4 Application of Big Data Interference Analysis

4.1 Setting Parameters and Building Model

At the beginning of interference analysis, we will set some parameters according to the previous test results and experiences. Besides, we will build a model for each front-end processor on the basis of continuous spectrum data for several days.

In our intelligent interference analysis system, the leisure time is from 1 to 5 a.m, while others are busy time. Besides, we set the minimum interference duration to one minute and the interference threshold to 15 dB, which means that the spectrum of the frequency point will increase by 15 dB when there is interference occurs. Moreover, we also set up the delay time of interference analysis for different base stations according to different traffic levels. In addition, the sleep time between two analyses is 30 min.

For each front-end processor, we choose two days of normal spectrum data, which need the field test to confirm whether there is interference in the data, to get the busy and leisure time model. The current selection strategy is to select the maximum data of busy or leisure time in the corresponding time period of two days at different frequency points as the model value of the different frequency.

After setting parameters and building model, we can start the application for continuous interference analysis.

4.2 The Application of Interference Analysis

On the basis of the above software and hardware, we implement the GSM-R monitoring system based on the GPP-SDR framework. Besides, our monitoring system has been applied into some Chinese railways, such as Wuhan-Guangzhou line and Guangzhou-Shenzhen line. Through the big data analysis, we have successfully monitored many interferences, which help to improve the reliability of the GSM-R system.

In June 2018, through the interference analysis platform, we discover an interference that occurred at a base station in Guang-Shen Line. The interference record is found through the software, as shown in Fig. 7 and Table 1. Figure 7 is the interference spectrum diagram and Table 1 is the detailed information about the interference.

According to the interference information, we can find that the interference happened at near 18 o’clock. Therefore, it was an interference in busy time which was defined from 1 to 5 a.m. From Fig. 7, we can also see that the interference is a narrowband interference. Since the channel 1019 is not contiguous to the TCH channel (1003 and 1016) and BCCH channel (1001) and the interference not satisfied with other specific conditions, the type of the interference was judged to other channel interference. In addition, this interference was most likely caused by the private amplifier, so the software determined the suspected source of the interference as the private amplifier.

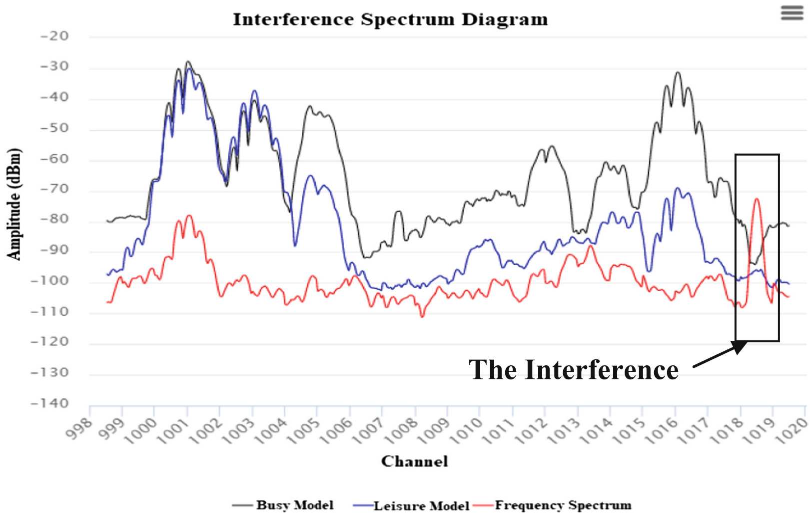

Fig. 7. The interference spectrum diagram

Table 1. Detailed information about the interference

Property	Value
Front-end processor number	450571032
Base station	ShiPai
Interference intensity	–69.226 dB
Interference bandwidth	0.2 MHz
Interference channel	1019
Strongest interference channel	1019
Type of interference	Other channel interference
Suspected source of interference	Private amplifier
Start-end time of interference	2018–06–10 18:28:53 ~ 18:30:42

In order to check this interference source, the tester used the spectrum analyzer to detect around the base station. As we expected, the result of the detection was roughly the same as that in Fig. 7. And then, the tester found the location of the most intense interference by changing the antenna position of the spectrum analyzer. Finally we found an illegal private amplifier on the roof of a residential building, as shown in Fig. 8. After we contacted the relevant department to deal with this illegal private amplifier, there was no similar interference in this base station.

Fig. 8. The illegal private amplifier in field tests

5 Conclusions

In this paper, we introduce our GSM-R monitoring system based on the GPP-SDR framework and big data analysis. Unlike the traditional methods mainly based on the A interface, Abis interface and PRI interface, our system is based on the Um interface which can better monitor the wireless channel and handle some interferences and faults that the traditional ways cannot deal with. In addition, we have successfully applied the monitoring system to some of the railways in China. And in practical applications, some of the interferences have been successfully monitored.

On the other hand, we will further optimize our monitoring system in the future to improve its performance. For example, we can develop the B/S structure to make it more flexible and use the machine learning methods to improve the efficiency and reliability of the big data processing.

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