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Analysis of Data Transmission Method Based on GSM-R Network and Teaching Platform for Wireless Network

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Abstract

Railway digital radio system, GSM-R, is a dedicated system for railway based on GSM system, which shoulders the demand of dedicated dispatching communication for railway. So it is extremely important to research the data transmission of GSM-R. In this paper, a data transmission method has been proposed, based on the actual measurement report of GSM-R and a prediction algorithm, in analyzing the relationship between Measurement Report and Transmission Interference through visualization method by using the data mining instruments. The simulation results prove that the probability of data being interrupted and retransmitted can be decreased by using this method. At the same time, a teaching platform is established for analyzing the actual test data and the simulation in high-speed railway system, which can contribute to the theoretical research and the teaching. And the mass data used in this paper comes from this platform.

Keywords: *GSM-R, Measurement Report, Transmission Interference, Data Mining, Teaching Platform*

1. Introduction

With the rapid development of high-speed railway and the increasing of the train speed, it calls for higher reliability, stability and security of wireless network in railway train control system. So it is extremely important to increase the success rate of train control information transmission. However, the handoff of GSM-R network is hard handoff, which means that the data transmission must be interrupted and will be retransmitted when handoff is occurred. In addition, the increasing of train speed will make handoff occur much more frequently. So a data transmission method has been proposed in this paper, by predicting the network environment with actual data and then reaching the probability of data transmission.

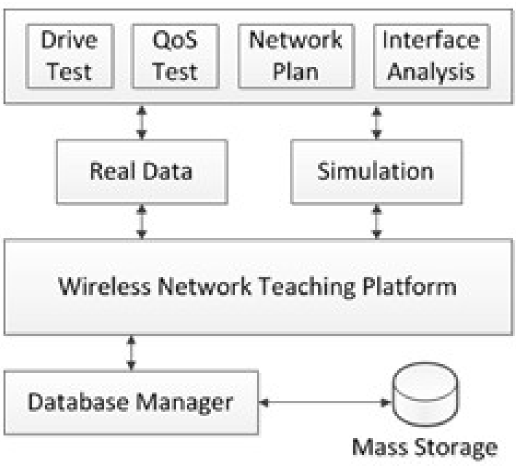

Figure 1. Teaching platform

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At the same time, a teaching platform based on the high-speed railway system has been established. In Figure 1, by accessing data from mass storage database, the platform provides the analyses of the actual test data and the simulation. The data of mass storage database come from the actual drive test and QoS test of high-speed railway in China. It not only contributes to the theoretical analysis of high-speed wireless network, but also helps to learn and understand the wireless network for the students. By searching the Drive Test data and QoS Test data, a sample with mass data has been accessed and used in this paper.

2. Measurement Report and Transmission Interference

When in dedicated mode or group transmit mode, the mobile station regularly sends Measurement Report messages to the network. These messages contain measurement results about reception characteristics from the current cell and from neighbour cells [8]. Reception Level (rxLev) ranges from -110 dBm to -47 dBm, and Speech Quality (rxQual) ranges from 0 to 7 of eight degrees.

GSM-R service quality evaluation system provides the KPI of Transmission Interference. The purpose of this KPI is to test the correct sending of data frames across the GSM-R subsystem [7]. Transmission Interference is composed of Transmission Interference Time (TTI) and Transmission Error-free Time (TREC). And some typical examples are shown in [7].

3. Data Visualization

By preprocessing the actual data from a section of Jinghu Railway, rejecting invalid measurement reports and searching if data is interrupted in a dedicate measurement report period, 109096 valid data items are accessed. This data sample has five columns of main cell rxLev, neighbor cell rxLev, rxQual, interference flag and kilometer record. Data mining is a process of discovering useful information automatically from library of large data storage [5]. Weka working platform, an open source data mining instrument, includes methods which can process all standard data mining [6]. A research of data visualization with Weka working platform is studied below.

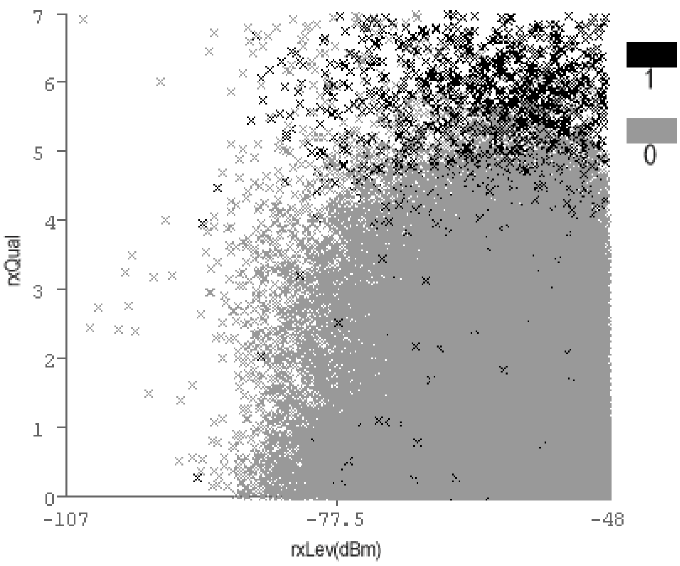

Figure 2. rxLev, rxQual and interference flag

We set main rxLev and rxQual as the axes, interference flag as classify attribute, and get the result as shown in Figure 2. Because the rxQual is discrete, and in order to see its distribution, we add jitter to this attribute. From Figure 2, it can be found that rxQual is the main influencing factor of Transmission Interference easily. When rxQual is larger than 4, transmission interference will occur. And we can also get this conclusion by using decision tree algorithm like J48 through data mining.

RxQual is discrete, and it is always 0 in railway environment with good field coverage, so it is not useful to control the data transmission as a parameter. Figure 3 is the histogram frequency distribution diagram of rxQual, and we can figure that the 0 value is about 72% in percentage. So the relationship between rxLev and rxQual should be researched. A strong correlation between signal strength and GSM signal quality is concluded in [2]. We set rxQual as classify attribute, and get the result as shown in Figure 4. But the relationship is not clear.

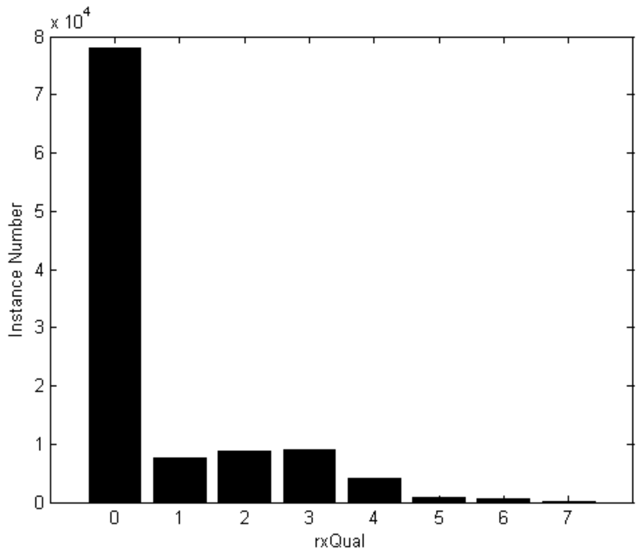

Figure 3. Distribution of rxQua

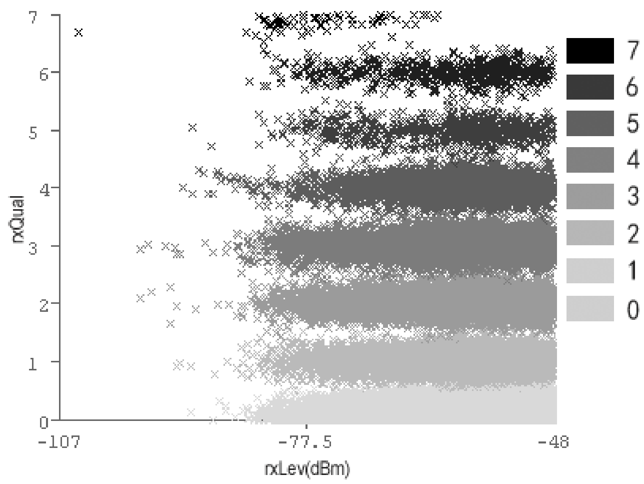

Figure 4. rxLev and rxQual

In the practical situation, the worse speech quality always occurs near handoff. And the main reason of handoff is preventive power handoff [3]. The neighbor cell rxLev must be above main cell rxLev with a certain threshold, which is called handoff margin, in order to increase the difficulty of handoff to prevent ping-pong effect. So we set rxLev difference between main cell and neighbor cell as the horizontal axis to research the relationship, and the result is shown as Figure 5. It can be found that when the rxQual is larger, the difference is smaller relatively, which means closer to handoff. And from the distribution of rxQual, we can conclude that the speech quality can be better or worse gradually. So the difference can be used as the parameter of the data transmission method.

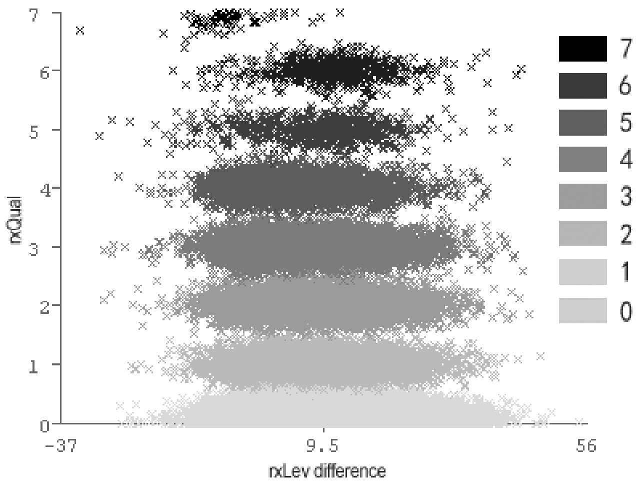

Figure 5. rxLev difference and rxQual

4. Research of Data Transmission Method

From the analysis mentioned above, it can be concluded that when the rxLev difference between main cell and neighbor cell is smaller, the speech quality is worse relatively. However, rxQual reflects the error rate of channel, and the reduction formula is shown in [4]. So we can use the rxLev difference to reach a probability of data transmission, and thereby decrease the probability of data being interrupted and retransmitted.

The data transmission probability is determined by the later rxLev difference, so the rxLev in the next Measurement Report period should be predicted. And we use AR module to do forward linear prediction. For time series {xt}, t = 1, 2, ⋯ , N, AR(N) is

$$x_t = \Phi_1 x_{t-1} + \Phi_2 x_{t-2} + \cdots + \Phi_n x_{t-n} + a_t,\quad a_t \sim NID\left(0, \sigma_a^2\right) \tag{1}$$

Parameters of Φ1, Φ2, … , Φn, can be estimated by some methods like Least Square Method, Yule-Walker Method, Burg Method and so on. And with these parameters, the prediction of rxLev can be calculated. In order to make the prediction more accurate, the quantity of samples used to do parameter estimation should be big enough. At the beginning, the train is far away from handoff position, and the field coverage is good, which will not influence the probability of transmission dramatically. So the first p of actual values can be used as the prediction values at the start, and after that all the values can be used to do parameter estimation to increase the accuracy of prediction.

By using prediction algorithm, the predicted main cell rxLev, mainRxLev(t), and neighbor cell rxLev, neighbourRxLev(t), can be got at t moment and we set

$$C(t) = mainRxLev(t) - neighbourRxLev(t) \tag{2}$$

The data transmission probability is

$$P(t) = \frac{\log_2^{\left(1 + K(n)\frac{C(t) - h(n) + \Delta(n)}{M - h(n)}\right)}}{2},\quad h(n) < 0,\quad \Delta(n) > 0,\quad 1 < K(n) < 3 \tag{3}$$

where n means a GSM-R base station, h(n) means the handoff margin of n base station, and M= Max{C(0), C(1), ⋯ , C(t)}. The signal strength value corresponding to a certain signal quality may vary more than 20 dB in different environments [2]. So two parameters, Δ(n) and K(n), is introduced. Δ(n) is mainly used to influence the probabilities near handoff, and K(n) is mainly used to influence the whole probabilities. So different values of Δ(n) and K(n) can be set focusing in different environments around n base station.

5. Simulation Analysis

A small data set of a handoff between two base stations is extracted from the data items mentioned above, and it is used in simulation by MATLAB. Figure 6 shows the rxLevs and rxQuals, and the vertical line is the actual handoff position. It can be found that as the rxLevs between two cells become closer, the qualities get worse. So it is viable to set rxLev difference as the parameter of data transmission method. The prediction results of rxLevs of two cells are shown in Figure 7. The N used to predict is 3, the quantity of samples p used to estimate is 16 at the beginning, and parameter estimation method is Yule-Walker method. It can be found that the prediction values are a little bigger than actual values in both cells. But the rxLev differences can meet the requirements.

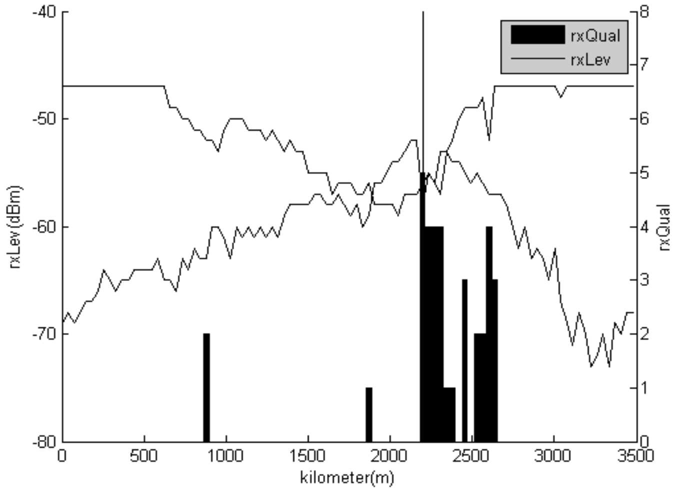

Figure 6. rxLevs andrxQualsof two cells

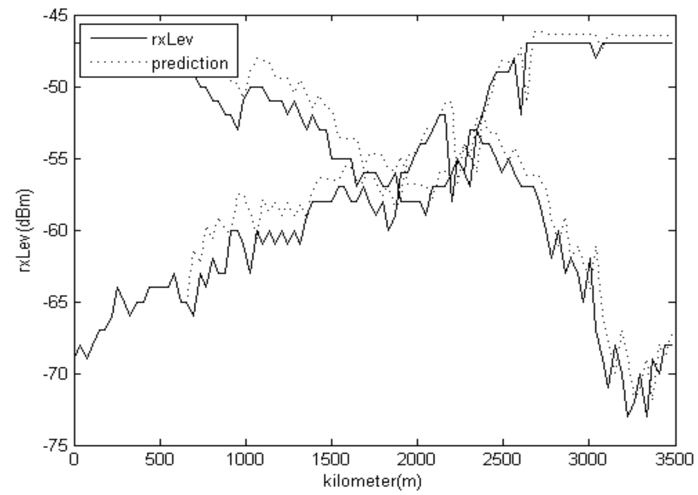

Figure 7. Predict and actual values of rxLev

The probability of data transmission calculated with the prediction values mentioned above is shown in Figure 8. Because the field coverage of this section is good, parameters of h(n), Δ(n) and K(n) are set h(n) = -5,Δ(n) = 5, K(n) = 1.3. It can be found that as the handoff is closer, the probabilities become smaller, which decreases well the probability of transmission interference that caused by the low speech quality shown in Figure 6.

In the actual transmission of train control information, the whole transmitting time [1] can be calculated by $T_I = \frac{L_I}{R_I} + \frac{L_I}{30}(1 + FER)T_d + \frac{L_I}{30} \times FER \times T_r$. By using the recommended parameter values in [1], and assuming the information to be 500 bytes long, the result of TI is about 9.6 s. The actual speed of train is about 280 km/h, so in the period of the information transmission, the train will drive about 746 m. So the probabilities of the information being interrupted are calculated of normal transmission in which the transmission probability is 0.5 and transmission in which the transmission probability is calculated with the method, and the results are shown in Figure 9. It can be found that by using the transmission method, the probability of data being interrupted is decreased by 18.2% relatively, and so the data retransmission can be avoided in a certain extent.

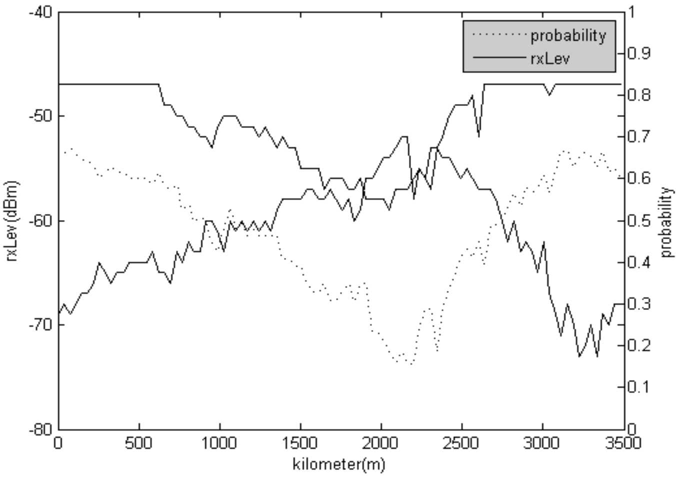

Figure 8. rxLev and probability of data transmission

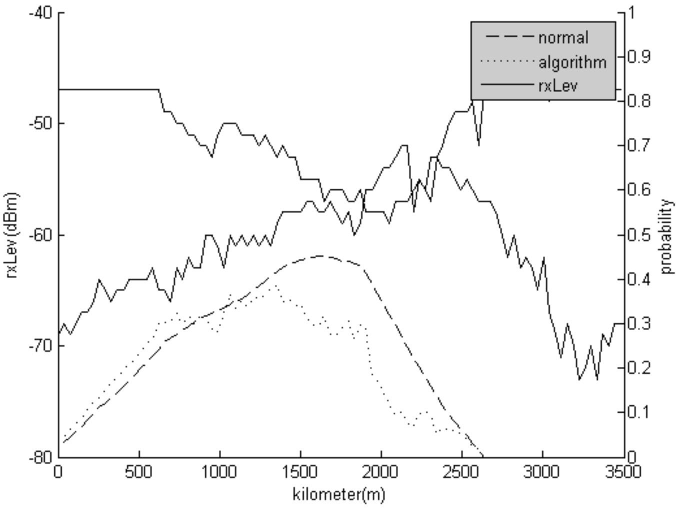

Figure 9. Probabilities of interference of normal transmission and transmission method

6. Conclusion

In this paper, an actual test data set from a section of Jinghu Railway has been accessed from the mass storage database of the teaching platform. And by using data mining instrument, we found that rxQual is the main influencial factor of Transmission Interference, and correlates to the rxLev difference between the main cell and the neighbor cell. Then a data transmission method has been proposed based on the actual Measurement Report and a prediction algorithm. This method is proved to decrease the probability of data being interrupted and retransmitted in the simulation.

Acknowledgments

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