Analysis and Forecast of Urban Rail Transit Network Based on LTE Signaling

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Abstract. According to the requirements of LTE-M in rail transit safety, this paper collected various data in LTE-M network without affecting the normal operation of the network, screened effective information from the mass data, and systematically designed the software with data analysis technology. Using the neural network algorithm to predict the signaling data, we can judge the future condition of the network, adjust the network in time and prevent the possible failure in the future.

1. Introduction.
The signaling monitoring technology designed for operators' public networks cannot fully meet the needs of LTE-M (LTE-Metro) signaling monitoring. This paper designs an LTE-M S1 interface monitoring system, which realizes remote monitoring of LTE-M network interfaces. The article introduces the overall design and software design of the system, realizes the acquisition, management and analysis functions of the S1 interface data, and runs and tests the LTE-M monitoring system software, and obtains the monitoring content data chart.

2. Overview of LTE-M

2.1. Research background and significance
In recent years, with the rapid development of the city, the traffic pressure is becoming more and more serious. As the main transportation mode of green transportation system, urban rail transit has the characteristics of safety, speed, comfort, punctuality, etc. At the same time, as the main force of fast distributing and distributing passengers, it can effectively solve the problems of large traffic flow and road congestion in the city. Communication Based Train Control System (CBTC) is adopted in urban rail transit lines. As an important part of the CBTC System, vehicle-ground wireless Communication is used to transmit Train Control information and Train status information. Since 2016, new urban subways have adopted LTE-M (Long Term Evolution for Metro) communication system to carry a variety of services.

In urban rail transit, the main task of the data communication system is to transmit communication messages between subsystems of the train control system. It is a subsystem of two-way information interaction between ground equipment and vehicle-ground equipment of the CBTC system. Once the fault occurs, the transmission of dispatch information and control information between the dispatch center and the train will be interrupted, which directly affects the normal operation of the CBTC system. Because the signaling contains a lot of information about the state of the system transmission equipment, it is very important to monitor the signaling of LTE-M network. In the current market, most of the
signalling monitoring equipment are designed for the public network. This paper mainly obtains data from the LTE-MS1 interface and uses software to analyze the data to monitor the LTE-M network, so as to help network monitors monitor and maintain the network and provide assistance for the daily safe operation of the LTE-M network.

2.2. Introduction to LTE-M

LTE-M is a TD-LTE system specially customized for urban rail transit applications. Compared with the services carried by LTE in the public network, LTE-M is oriented to the rail transit industry, including train service control data and train operation status. Information, emergency information text distribution business, video surveillance, passenger information system streaming media business, cluster dispatching business. The network architecture of LTE-M is completely consistent with LTE, including two parts: radio access network and core network. The core network includes MME (Mobility Management Entity), HSS (Home Subscriber Server), and SGW. (Service Gate Way), PCRF (Policy and Charging Rules Fuction), PGW (Packet Gate Way) and other network elements, the Uu logical unit is mainly for UE and eNodeB for interface services, when When the UE accesses the core network, the function of the PWG is to have the UE's bearer management function and to assign an IP address to the UE; the SGW has the routing function to be responsible for user plane data, and to perform mobile positioning when the eNodeB is handed over; the MME is mainly responsible for Send calls to eNodeB, manage eNodeB and other mobility list management, can perform bearer management, etc., can provide services such as PGW and SGW selection, is a control plane network element and a server that can store UE; PCRF is mainly responsible for network services and Resource strategy: eNodeB is used as a network element. When the UE is connected to the core network, its main function is to encrypt the user data stream, which can be routed to the SGW by selecting the MME, and has the function of paging message transmission, priority scheduling function, etc.. The radio access network includes the eNodeB, which is responsible for functions such as user data encryption, MME selection, and paging message delivery[1]. The LTE-M system structure diagram is shown in Figure 1.

![Figure 1 LTE-M system structure diagram](image)

2.3. LTE-M S1 interface protocol

The S1 interface refers to the interface between the base station and the evolved packet core (EPC) in the LTE system. There are two types of signaling transmitted through the S1 interface on the control plane. The first type is S1AP protocol signaling for communication between eNodeB and MME; the second type is non-connected signaling used for communication between user equipment (UE) and MME For non-access stratum (NAS) protocol signaling, an S1 connection between eNodeB and MME
needs to be established before eNodeB and MME send S1AP messages. The S1 connection is divided into two levels:

1. S1 connection of eNodeB: It is the connection between eNodeB and S1AP entity of MME. When the eNodeB enters the network, it will actively establish an S1 connection with the MME. This S1 connection has nothing to do with the UE, even if the eNodeB is empty. The eNodeB obtains the MME’s SCTP Endpoint IP/Port through static configuration or querying Local DNS, and actively requests the MME to establish an SCTP association (SCTP Association): eNodeB sends S1 SETUP REQUEST to MME, MME sends S1 SETUP RESPONSE to eNodeB, and both parties exchange Configuration (such as eNodeB ID and TAI of eNodeB, GUMMEI and RMC of MME), the S1 connection of eNodeB is established.

2. UE's S1 connection: it is a logical connection associated with the UE. Since eNodeB and MME serve more than one UE, eNodeB and MME distinguish between each UE by establishing different S1 connections and send corresponding S1AP messages. The eNodeB S1 connection is the basis of the UE's S1 connection. The UE's S1 connection is always initiated by the eNodeB: when a UE enters the network, the eNodeB receives the first uplink NAS message (e.g. UE ATTACH REQUEST) from the NAS PDU of the RRC message, and immediately allocates the eNodeB UE S1AP ID to the UE, and included in the S1AP message INITIAL UE MESSAGE sent by the eNodeB to the MME. Subsequently, the MME shall allocate the MME UE S1AP ID to the UE and include it in the S1AP message DOWNLINK NAS TRANSPORT (carrying NAS messages such as ESM INFORMATION REQUEST or AUTHENTICATE REQUEST) sent by the MME to the eNodeB[2].

3. Design of System Architecture

3.1. Data collection
The data acquisition module contains two main functions: data capture and data decoding.

3.2. Data management
The data management module is the central module of the system. Its main functions include: data interaction between modules, data processing, data transmission, data storage, the use of related configuration files and log files, and auxiliary functions.

3.3. Data transmission and storage
In actual application scenarios, core networks are often distributed in different locations. In order to solve the problem of collecting core network data at different locations, this topic proposes a set of solutions to remotely transmit and store data. Deploy a monitoring device at each location where core network data needs to be captured. The monitoring device processes the captured data packets and uploads them to the server. The data can be stored in the server for a period of time. The remote master monitoring equipment can obtain all the data of the S1 interface of the core network from the server, and the data can be processed again on this equipment.

3.4. Data analysis
The data analysis module is after acquiring data and data management, its function is the data analysis function in the process. It obtains data from the data management module, uses the algorithms in the module to process the data, and feeds back the obtained results to the data management module, and the data management module then makes corresponding processing based on the data.

4. Design of Software Module

4.1. Neural network in this system
The input data of the neural network of this subject is text data, which is captured from the LTE-M S1 interface, decoded, and filtered.
This topic calculates the number of signaling messages and the number of valid data packets per unit time, where the number of valid data packets per unit time refers to the number of data packets of signaling messages. The data first accesses the preprocessing layer. Since the preprocessing layer gets the signaling message and the number of valid data packets per unit time, the preprocessing layer will use the signaling message data as the input of the next layer of convolution. The number of valid data packets per unit time will be used as the input of another set of BP neural network.

After the preprocessing layer gets the input data (the data here is the message after a screening), it will first analyze the number of packets contained in a data set, and send this number of packets to the BP neural network for calculation. The BP neural network has two inputs, so the number of packets is also set to two and then used as the input data of the BP neural network. After completing the statistics on the number of packets, the preprocessing layer will analyze other data, here mainly signaling data. The preprocessing layer will convert the signaling data into a digital sequence according to the dictionary, and then each signaling in the data set will be integrated into a 2-dimensional feature map in digital form. The 2-dimensional input feature map will be processed in the convolutional layer, and the convolutional layer will use a 2*2 filter for convolution, and the weight of the filter can be obtained during CNN training[3]. The reason why one-dimensional data is converted into two-dimensional data here is because the amount of input data is huge, and this data matrix can be regarded as data in a certain period of time.

The data will then enter the pooling layer. Since communication failures are the main problem to be explored in this topic, the features extracted at this layer should mainly be signaling messages that cause communication failures.

After that, the data will be processed by the fully connected layer. Each unit in the fully connected layer will be connected to all the units in the previous layer. After the calculation of the fully connected layer, the output will be obtained.

Through the output obtained, the frequency of the data packet, the length of the data packet, and the probability of the specified signaling appearing in a certain period of time in the future can be obtained from it. Staff can use this to judge the future network status, and can make adjustments to the network in time to prevent possible future failures.

4.2. The output of the neural network

The convolutional neural network part of this topic uses some python programs, calling the Keras library[4], using signaling data as the training set and test set of the convolutional neural network, and using the classification function of the convolutional neural network to classify various signals. Let the data, and then use the neural network to predict the probability of each signal appearing on the test set. Figure 2 shows the predicted probability of part of the signaling, and Figure 3 shows the actual probability.
The above two figures are the comparison between the predicted value of some signaling in the neural network and the actual value in the actual captured data packet. The error between the predicted value and the actual value is small. Using the above data can help relevant personnel judge the future data volume, and can load balance the network in time or maintain the network in time to avoid network failures.
5. conclusion
This paper first introduces the lte-m system architecture and the content of S1 interface protocol stack, and makes clear the source of monitoring data and interface protocol. The BP neural network is used to predict the frequency of data packet and the probability of lte-m signaling. Compared with the actual value, the error is small. This can help the relevant personnel to judge the amount of data in the future, can do load balancing for the network in time or maintain the network in time, to avoid network failure.

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