Research on the Monitoring Method of the Road Communication Network Quality Based on Vehicle Borne Internet of Things

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Abstract. This article proposes a monitoring method of the road communication network quality based on vehicle borne IoT (Internet of Things) by extracting and analyzing the MR (Measurement Report) data from the bus in the vehicle borne IoT to monitor the wireless network quality on key highways and to efficiently and accurately locate and detect the network errors. This method has proven to be accurate and meets the practical demands. It can further enhance the accuracy and timeliness of network evaluation and its impact in tremendous on increasing the stability of the quality of Mobile Telecommunication Networks.

Keywords: Vehicle · Internet of Things · Monitor method
Mobile network · Measurement report

1 Introduction

Mobile Communication Networks are the important Internet carrier to realize vehicle borne IoT. The vehicle borne IoT is a cutting-edge technology, which involves installing the communicating terminal on vehicles and connecting the vehicles on the Internet to establish wireless communication among driving vehicles in order to substantially elevate the security and efficiency of future transportation system. With the increased speed and carrying capability of the 4G internet, the vehicle-loaded Internet will become an important component of future intelligent transportation system. Meanwhile, the quality of the Mobile Communication Networks needs to be highlighted [1]. The traditional method involves monitoring the road network via DT (Drive Test), that is measuring the

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performance of the wireless network by driving along the highway, which is inefficient and at a high cost [2–4]. It is realistic now to monitor the wireless network quality along the highways accurately and efficiently with the bus connected to the IoT.

The Measurement Report, abbreviated as MR, is the chief gauge of the quality of the wireless network environment, sent via mobile phones to the Internet system, which includes the information of base station detected, reception level and quality. This article proposes a new method to evaluate the quality of the road mobile network based on vehicle borne IoT to realize the accurate locating of the mobile users along the highway, assisting the monitoring on the road network quality to optimize the targeted area and increasing the efficiency of supervision on network quality.

2 Method to Monitor the Wireless Network Quality Based on Vehicle Borne IoT

2.1 Object of Supervision and Control

The vehicles are consistently connected to the vehicle borne IoT, therefore MR data can be extracted and analyzed via the number and type of the communication terminal installed on the bus known. For example, there are more than 3200 buses installed with communication terminal available in Shenzhen Bus Group with a broad monitoring area covering all the arterial roads and highways (Fig. 1).

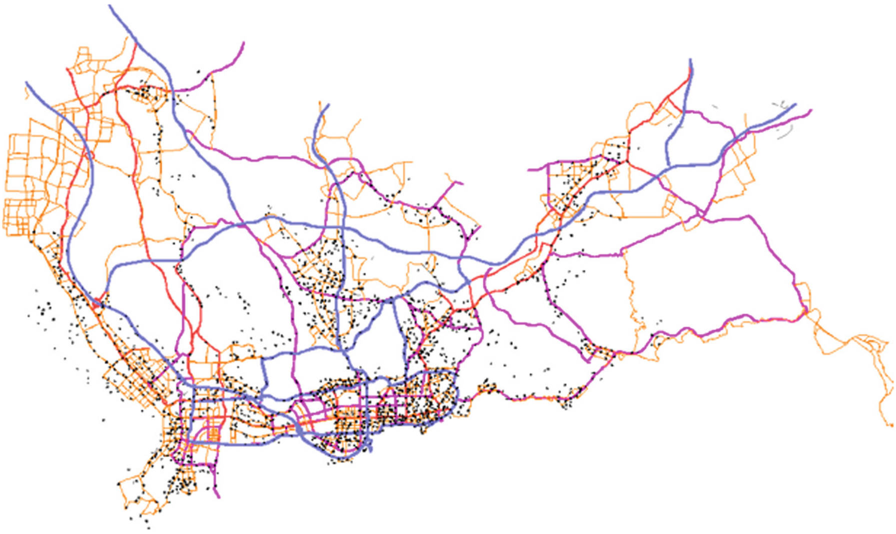

Fig. 1. The route map of the buses in the vehicle borne IoT in Shenzhen

2.2 The Multiple-user Base Station Switching Chain Algorithm

The difficulty of conducting road network detection based on the MR data extracted from multiple users lies in how to decide the base station switching chain on the targeted road. This article proposes a new sequencing method to realize the sorting of base station switching chain and data analysis.

This sequencing method contains three components, including the segmentation and arrangement of MR, cross banding, and the calibration of the standard switching chain. The flow chart of this sequencing algorithm is as follows:

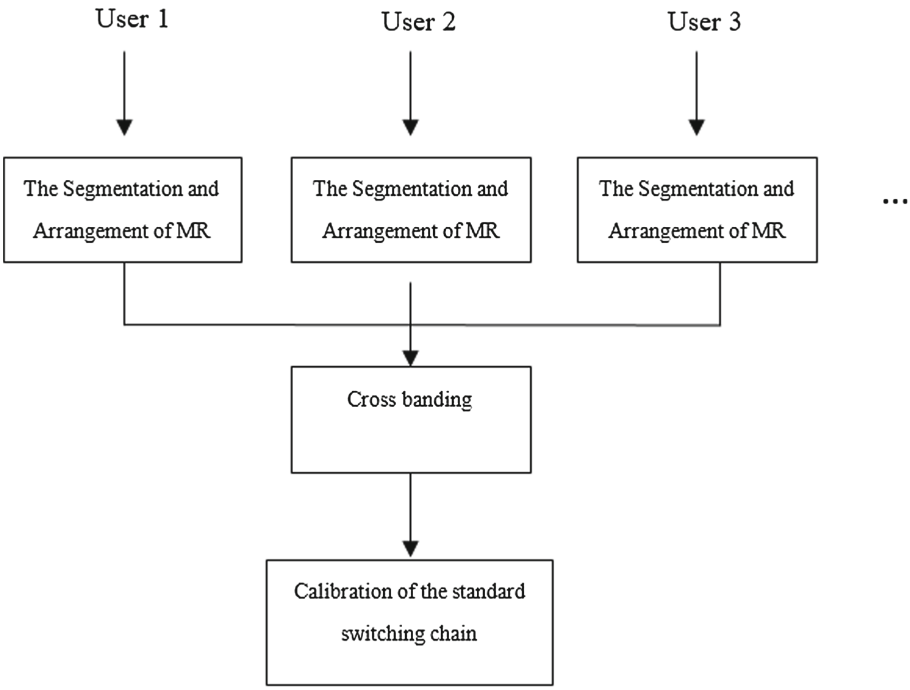

Fig. 2. The flow chart of base station switching chain algorithm

(1) The segmentation and arrangement of MR data: The aim is to segment the MR data into multiple-sectioned return switching chain, including the go sequence and return sequence to identify the direction the bus is going.
(2) Cross banding: Integrate the dispersion sequence of the multiple return trips conducted by multiple users into one sequence.
(3) The Calibration of Standard Switching Chain: Update and calibrate the standard switching chain when the circuit is changed or a new Internet station is established (Fig. 2).

2.3 An Accurate Position-marking Method Based on RTT

To realize the accurate locating of the bus on the road, taking the WCDMA system as an example, the Measurement Report contains RTT fields to log the

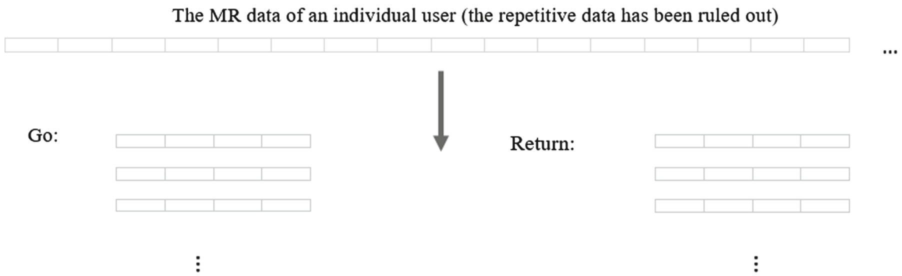

Fig. 3. The segmentation of the MR data

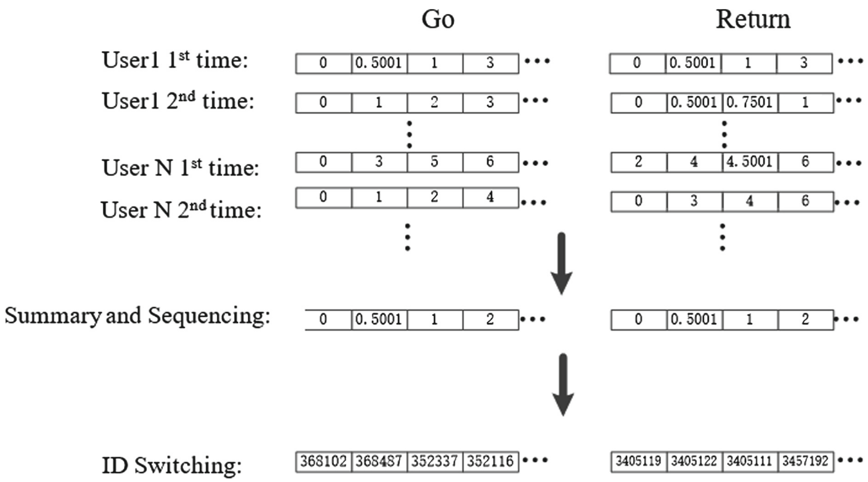

Fig. 4. The cross banding of MR data

time consumed by the signal in a return trip from the terminal to the base station. The linear distance between the terminal and the base station when it is sending the measurement report to the base station can be calculated based on RTT. According to the exact definition of MR fields in the 3GPP protocol, the calculation is as follows [5]

$$dist = \frac{3 \times 10^8}{3.84 \times 10^6} \times \frac{1}{2} \times [\frac{rtt}{16} + 876 - RxTxTime] \quad (1)$$

In the formula above, 3×10^8 is the speed of radio wave, 3.84×10^6 is the chip rate in WCDMA, *dist* is the distance between the user and the base station in reality (Figs. 3 and 4).

It is noted that this formula can only be applied in the WCDMA system as the parameters and protocols vary from one system to another, as the result, the formulas used are various. In the case of GSM and FDD-LTE system, the core principles of the two are the same, but the parameter in equivalence with RTT is named TA (Timing Advance), and the formulas used are different.

In step 1, the longitude and latitude are known, we can therefore calculate *dist*, and draw a circle with the base station as the center and *dist* as radius. There are at least two intersection points on the highway. As the specific sections covered by the base stations are already documented in the MR, with the azimuthal angle of the aerials, we can then measure the equivalent point of MR.

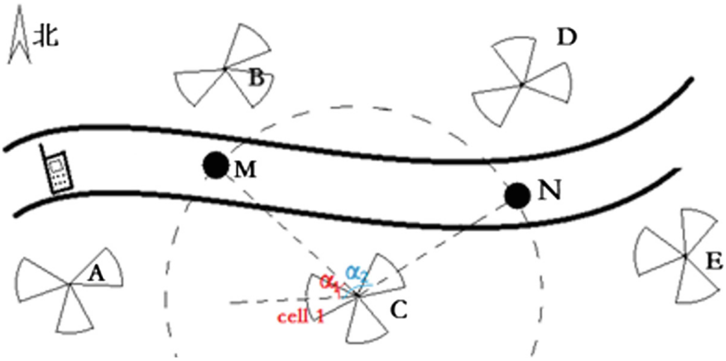

Fig. 5. The accurate locating of users on the targeted highway

As is shown in Fig. 5, cell 1 collects the users MR in the current spot, and then calculates *dist* and the longitude and latitude of the base station to locate two points M and N. The azimuthal angle of CM and CN between the aerials are α_i and α_2, $\alpha_1 < \alpha_2$. It can be deduced that M is the equivalent point of the user. Given the longitude and latitude, M can be color marked indicating the intensity of the signal. If there are more than one MR equating to the same point, an average can be drawn.

$$\frac{E_c}{I_{o_{total}}} = Avg(\frac{E_c}{I_o}) \tag{2}$$

2.4 Filling the Blank Area on the Road Map by Spreading the Point

As the reporting cycle of MR is fixed, there appear to be blank areas on the highway. Further spreading of the data is required to ensure the completion of monitoring data of the whole highway.

$$V_{i+1} = \frac{(V - V_i) \times (r - \frac{1}{2})}{r} + V_i \tag{3}$$

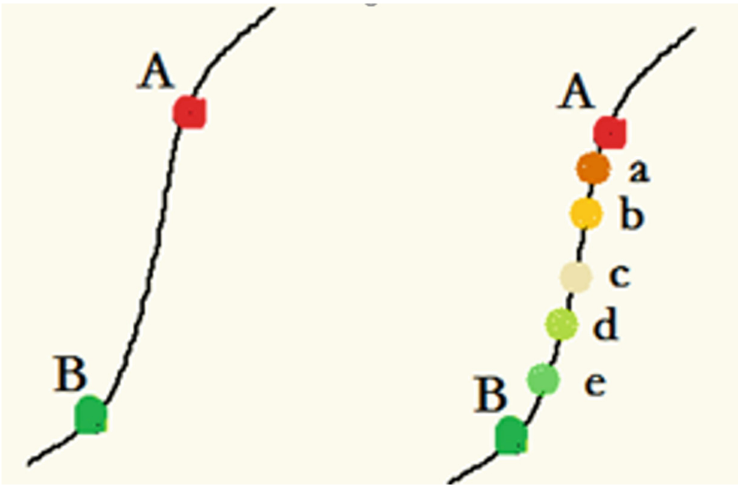

Fig. 6. The cartography of the road network quality (Color figure online)

In the formula above, V is the numerical value of the spread point, Vi is the i-th point to the spread point, and r is the number of spread points of the target.

In Fig. 6, A and B are acquired by the method illustrated above. A represents low signal intensity marked by the color red and B represents high signal intensity marked by the color green. There is a blank belt between A and B. To fill the gap, based on formula 3, we take $r = 5$, A and B as datum points, calculating the signal intensity of the five points a, b, c, d and e between A and B and then marking on the map to render a fluent flow between A and B.

In addition, if there appears to be an inconsistency or breakdown of the base stations covering a large area, as the result, the MR sent from users mobile phones will not be received. As a consequence, there will be a large blank area on the map. Therefore, based on the large blank area on the monitoring map, it can be deduced that there is a breakdown or inconsistency of the base station. This method has realized the monitoring of network breakdown to ensure the quick locating of the fault locations and the area affected.

3 Application Result and Analysis

Taking the WCDMA system as an example, when this method was adopted to evaluate the quality of the network along the roads in Shenzhen, the result is as follows. The result from this method and that of the DT evaluation test are compared in the following table. The error rate is kept within ±10% to ensure that the evaluation result is valid (Table 1).

Table 1. The comparison of the results of the two network quality evaluation methods

Shennan avenue	The new method	Traditional DT test	Relative error
Total sampling points	1764	1695	4.1%
Coverage sampling points RSCP>−85 dbm	1685	1627	3.6%
Coverage rate	95.52%	96.04%	0.5%
Bad quality sampling points Ec/Io<−12 dB	45	40	-
Bad quality rate	2.55%	2.37%	7.6%
Consistent bad quality sampling points	4	4	0.0%
The quality during ping-pong handover	−9.6	−10.1	5.0%
Frequency of serving cell alteration	814	806	1.0%
Frequency of ping-pong handover	115	110	4.5%

4 Conclusion

This article presents a method to evaluate the quality of road communication network based on vehicle borne IoT by extracting and analyzing the MR data from the bus connected to the vehicle borne IoT to realize the accurate locating of

Fig. 7. Marked road map

the bus and to conduct quality supervision and control over the wireless network along the key roads, efficiently and accurately locating and detecting Internet errors. This method can also be applied to LTE and other network systems. The advantages of this method are as follows: (1) Accurate locating of the quality of the road networks; (2) More accurate and effective evaluation data; (3) Lower cost of road test; (4) MR data can be obtained with available facilities without large-scale investment (Fig. 7).

In conclusion, the new method proposed in this article can realize the real-time and whole-network backstage monitoring of the Mobile Telecommunication Network along the highways in aim to ensure the real-time feedback and location. It can be applied universally and has huge promotional value.

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