Fault location of power communication network based on dichotomy search algorithm

LiChao 1, Hu Youjun 1, Zhang Hao 1, Zhang Wenqiang 1

1 Nanjing Nari Information Communication Technology Co. Ltd, Nanjing, Jiang Su, 210000, China

Corresponding author’s e-mail: 770678350@qq.com; huyoujun@sgepri.sgcc.com.cn; 304348601@qq.com; zhang_w_qiang@163.com

Corresponding Author: LI Chao; email: 770678350@qq.com; phone: 13465818780

Abstract. In the quality degradation fault location of the power communication network, the focus of the power communication network quality degradation fault location is to reduce the test packet transmission and speed up the fault location time on the basis of accurate positioning. This paper first analyzes the traditional solar winds segment-by-segment detection and related research, which has a long positioning time, a large number of packets, and the continuous crowding of communication resources at the normal communication link during the test. In this paper, binary search algorithm is applied in fault location, at the same time, source and destination nodes are orderly exchanged during fault location. Finally, the advantages of this method in reducing positioning time, reducing the test case packets and resource crowding are verified through simulation and engineering practice.

1. Introduction

With the development of communication technology, the scale of the electric power communication network is more and more large, especially with the construction of ubiquitous power Internet of things, the quantity of communication service is blowing out, the failure rate associated with traditional communication network failures, such as communication interruption, is already very low. However, due to the diversity and complexity of power communication services, the failure rate of power communication network has been increasing due to the over-limit of network quality. Moreover, based on different types of power communication services, there are differences in network quality overrun indicators. Some power communication service failures are caused by the over-limit of time-delay index, some power communication service failures are caused by the over-limit of jitter index, etc. Once the power communication network over-limit fault occurs, if the location of the over-limit fault is not diagnosed in time, it will lead to a sharp decline in the quality of power communication related services, which will have a great impact on the safe and stable operation of the power grid.

At present, researches on fault location of power communication network mainly focus on the following two aspects: The first is fault location based on on-off faults of communication network. When this kind of fault occurs, the alarm will be displayed in the system, and the alarm information will be used to continue to locate the device port and so on. This kind of research is very detailed, mainly including alarm information association judgment method based on data mining [1], power communication network fault location research based on bayesian and binary graph model [2], and network fault link diagnosis using fuzzy neural network method [3], [4] and so on.
At present, in the research of end-to-end fault location theory, literature [5] and [6], as representatives, adopt the method of minimum loss for fault location, but the key factor of location time is neglected in fault location. In the practical study of end-to-end fault location, literature [7] uses the extension mechanism of LB test method, However literature [7] does not support the rich variety of test cases, at the same time, the first half of the communication resources will continue to be occupied during the fault location process during the process of detection. At present, the end-to-end fault location of network flow analyzer solar winds is detected segment by segment. It takes a long time to locate the fault due to sending test packages segment by segment, and it also has the problem of continuous resource crowding in the normal section during the detection process, especially when the fault location is in the second half, the problem of resource crowding is prominent. In reference [8], a segmented test session mode was established between the probe and the special reflector NanoNID, but no specific segmentation method was given. Other schemes, such as FCS test and OAM performance test, it is difficult in locating fault degradation and cannot conduct detailed performance degradation analysis according to specific business.

For the current positioning time is too long, the amount of packet to the network in the positioning process is large, and the continuous occupation of non-fault segment channel causes resource waste. Flexible probe technology can be used, this paper uses the software probe test cases diversity advantage to meet the electric power communication business, by using the binary search, fault location can in effectively reduce the time of fault location. At the same time, we can use the test results to modify the source address and destination address, when the fault location is located in the second half of the cases. It can largely reduce the normal period of communication resource that is occupied by test case. At the same time, in terms of the average time of fault location, the average number of packets, and the average test cost, the binary search algorithm based on exchanging source address and destination address by using the test result is better than solar winds and literature [7].

2. Power communication service characteristic index threshold setting

For specific power communication services, more accurate communication quality index data are needed. Therefore, according to literature [8], There are six kinds of typical power communication service quality requirements. It is necessary to determine specific index data from the perspective of time delay and bandwidth limitation.

When setting the threshold, the specific network quality requirements of power communication service are taken into account. As shown in table 1. For EF queue, it mainly carries narrowband and real-time class service. For AF4 queue mainly carries broadband and real-time services, AF3, AF2 and AF1 are analyzed in accordance with table 1. The threshold values in the following table are obtained according to the service and queue category.

The different power communication services belongs to different queue (CS, EF, AF, BE), and different queue has the different the DSCP values, test case packages are given different values to match the corresponding power communication service. It make the test results reflect the quality of electric power communication business service. by this way, quality management of power communication networks is realized.

| Service queue | time delay | Packet loss ratio |
|---------------|------------|-------------------|
| EF            | 5ms        | 0                 |
| AF4           | 10ms       | 1e-4              |
| AF3           | 10ms       | 1e-4              |
| AF2           | 100ms      | 1e-4              |
| AF1           | 100ms      | 1e-4              |
3. Three-layer and two-layer fault location based on binary search algorithm

3.1 Discovery of topology nodes and storage of sequence relations
During the periodic test by using the probe device, the probe device can query the node topology of the probe device and the remote device through the topology relationship, as shown in Figure 1. The address can be stored according to the sequence relationship. The sequence table is shown in Table 2.

| Ordered list | IP address       |
|--------------|------------------|
| ①            | 10. 21. 40. 26   |
| ②            | 10. 21. 40. 1    |
| ③            | 10. 0. 0. 129    |
| ④            | 10. 0. 0. 105    |
| ⑤            | 10. 0. 0. 17     |
| ⑥            | 10. 0. 0. 18     |
| ⑦            | 10. 129. 2. 2    |
| ⑧            | 10. 129. 40. 147 |

3.2 Binary search fault location
The network node can obtain the network indicator data of the detecting device to each intermediate node by sending a test case package to each node obtained by the binary search algorithm, and finally the fault segment location can be located. When the index of a fault segment exceeds the limit value, the fault segment can be identified by warning color in the route, so as to locate the fault segment. The fault location process is shown in figure 2.

Fig. 1 Query to get through the topology node

Fig. 2 Binary search method

3.3 Description of binary search algorithm
Since the test case package can often calculate the delay, the bandwidth, and the corresponding packet loss rate during the test, when there is any quality degradation of the indicator in the measurement index, it can be determined that there is a degradation fault.

Parameter description: \(\min_{ip} , \ max_{ip}\) is the number corresponding to the starting IP address and the host IP address of the order table; \(\text{mid}_{d}\) is the IP address number of each binary search location; \(\min_d^{(1)}, \min_d^{(t-1)}\) and \(\min_d^{(k)}\) are iteration parameters in the iteration process. \(t\) is the loop parameter, that is, the parameter \(t\) is increased by 1 for each fault test. \(t\) is set to an initial value of 1. The \(k\) parameter serves as a marker for backward positioning, and the \(k\) value can take any value that \(k < t\). So in this case \(k = -1\).
If quality deterioration occurs, there is a fault from source node to destination node. The source and destination node should be modified next. The IP address serial number of destination node should be set to the starting IP address serial number., it is \( min_d^{(t)} = mid_d \). During the next probe, The IP address sequence number of the destination node is set to \( mid_d \), it can be calculated by \( mid_d = (min_d^{(t-1)} + min_d^{(t+1)}) / 2 \). Then, the test case package can be send from \( mid_d \) to the destination node \( min_d^{(t-1)} \), then carry out \( t = t+1 \) and \( k = t-2 \). And it should be sure that whether there is any quality deterioration during this test.

If there is no quality deterioration occurs, the network segment quality between the source with destination node. and the destination node location has not been degraded at this moment. The destination node of this probe should be set to the source node of the next probe. The address number of the source node is calculated by \( min_d^{(t)} = mid_d \). The destination node for the next probe should be set to \( mid_d \), The address number of the destination node can be calculated by \( mid_d = (min_d^{(t-1)} + min_d^{(t+1)}) / 2 \). Then, The new source node sends a test case package to the new destination node and conduct \( t = t+1 \). Whether there is any quality deterioration in the interval of this test.

In the process of calculation, integer function can be selected to ensure that the calculation result can be located to specific routing (or switch) location. Its flow chart is shown in figure 3.

3. 4 positioning sequence
Fault location of a layer 2 or layer 3 network can be located as follows: first, the layer3 network will be fault located by using the binary search algorithm based on IP address. the layer2 network will be fault located by using the MAC Address. The fault location can be located from layer3 to layer.

4. Case study
An example is given to simulate the power communication network in this paper. It is assumed that a communication network has 24 nodes, and some kind of power communication service quality deterioration occurs. The topology nodes from its source node to destination node can be obtained through query. The source node is V1, and the destination node is V22. The topological nodes of the degraded power communication service is from V1 to V22 (V1 → V2 → V3 → V4 → V16 → V17 → V18 → V19 → V9 → V10 → V11 → V12 → V24 → V22). There are 15 nodes in total.

Therefore, a 15-node communication link is generated and corresponding time delay, bandwidth and packet loss rate limits are set respectively.

In this paper, Matlab is used to simulate the time of fault location and the quantity of outsourcings. It is necessary to calculate the time and quantity of fault location according to the location of different fault segments. Therefore, in fault location, it is assumed that the time of fault location is determined by the number of network segments traveled by its packets. Meanwhile, considering the delay characteristics of the actual communication network, in order to facilitate comparison, the calculation scheme of communication network delay in literature [10] is adopted. Therefore, transmission delay, processing delay and queue delay are set respectively.

Let the transmission delay be \( t_1 = 5us / km \), and each distance is \( 1km \), so \( t_1 = 5us \). The processing delay is \( t_2 = 40us \), queue delay is \( t_3 = 20us \), \( x_1 \) represents the number of network segments traveled by the test package, and \( x_2 \) represents the number of nodes traveled by the test package. As for the different fault segments, total time of fault location is \( t = x_1 * t_1 + x_2 * (t_2 + t_3) \).

During the process of measurement, each measurement based on software probe technology varies with the location of faults. By comparing literature [7], the traditional segment -by-segment test method and binary search algorithm, the time of fault location is finally obtained as shown in figure 4, and the quantity of parcel delivery required for fault location is shown in figure 5.
As shown in figure 4, the fault location algorithm presents different location times with different fault locations. In this regard, for the traditional segment-by-section monitoring of solar winds, the time of fault location is getting longer and longer as the fault location moves back. For the method described in literature [7], the time of fault location is also increasing with the backward location of fault location. In terms of mean fault location time analysis, the mean fault location time of traditional solar winds is 1.932ms. The mean fault location time of literature [7] is 4.3ms, while the mean fault location time of the alternate binary search scheme of source code is 1.35ms. Therefore, the binary search algorithm has a great advantage in location time.

The number of test packet is shown in figure 5, no matter the traditional Segment-by-section detection with solar winds as the representative or the method described in literature [7], the number of test case packet is consistent and linearly increases with the backward offset of fault segments. As for the binary search algorithm, the number of packets issued by the fault segment at the position of 1, 2, 3 and 4 in this example is higher than that of the other two methods. When it is for later fault locations, the number of outposts remains stable. On average, the average packet of traditional solar winds is 150 test cases. The average packet of reference [7] is 150. However, the average packet of this paper’s binary search algorithm is 88.57. When the binary search method locates the fault location, the average quantity is the lowest.

Fig. 3 Flow chart of binary search algorithm

\[
\begin{align*}
    t &= 1 \\
    k &= 1 \\
    \text{min}_d(0) &= \text{min}_ip \\
    \text{min}_d(1) &= \text{max}_ip \\
    \text{mid}_d(0) &= (\text{min}_d(0) + \text{min}_d(1)) / 2 \\
    \text{min}_d(t) &= \text{mid}_d(t) \\
    \text{mid}_d(1) &= (\text{min}_d(1) + \text{min}_d(t)) / 2 \\
    t &= t + 1 \\
    k &= k - 1 \\
\end{align*}
\]
During the sending of test case messages, test case messages crowd out normal service resources. In particular, the segment-by-segment test of solar winds and the scheme in literature [7] will continue to squeeze resources from links in normal segments during the test, affecting the normal communication services and increasing the test cost. This paper describes the resource crowding problem as a cost problem. Therefore, this paper reflects the resource crowding problem through the test cost.

When the selection of test mode is unreasonable, there will be continuous congestion of test case messages in some link segments, which will occupy more resources. Since the aggregation layer undertakes access to many data streams, its test cost is higher than that of the access layer, while the core layer network nodes have the highest test cost, because they rent public network resources. In order to further determine the cost of network link test, resource investment analysis of xingtai communication network shows that the ratio of communication maintenance resources investment of core layer, convergence layer and access layer is 4:2:1 respectively. Therefore, the proportion of investment resources is taken as the test cost value of different levels, that is, the single link test cost of access layer is 1, the single link test cost of aggregation layer is 2, and the single link test cost of core layer is 4. In
the whole network of xingtai, the access layer network node accounts for 20%, the sink layer node accounts for 30%, and the core network layer node accounts for 50%. Therefore, node types are set in the same proportion in the example. Among them, there are 6 links located in the core layer, 2 aggregation layers is on each side, and 2 access layers is for equipment initial access. It is assumed that the cost calculation scheme of cost link test is:

$$\sum_{i=1}^{l_1} c_1 + \sum_{j=1}^{l_2} c_2 + \sum_{k=1}^{l_3} c_3 = y$$

(1)

![Fig. 6 Fault Location Test Cost](image)

In this case, \(l_1\) refers to the number of links in the access layer, and \(c_1\) refers to the link test cost of a single access layer. \(l_2\) is the link of sink layer, \(c_2\) is the link test cost of a single sink layer; \(l_3\) is the core layer link number, \(c_3\) is the core layer test cost; Its test cost value is set to \(c_1 = 1, c_2 = 2, c_3 = 4\) proportionally. \(a, b, c\) is the link number of access layer, link layer and core layer respectively.

As shown in figure 6, binary search fault location cost falls into two situations. When the fault location is in the first half, the test cost of fault location is the highest, while when the fault location is in the second half, the test cost of fault location is the lowest. As for the two fault location methods represented by reference [7] and solar winds, the test cost increases linearly with the backward fault location. Therefore, when the fault location of power communication network is located in the second half of the case, the binary search algorithm for orderly replacement of the source -destination node has a great advantage in test cost.

5. Conclusion
Software probes have obvious advantages in flexible deployment and test cases. The binary search algorithm is used in the fault location process, and the source and host node positions are continuously exchanged during the fault location process. Compared with the traditional solar winds and the literature [7], the method of this paper has great advantages in terms of average fault location time, average number of packets, and average fault location cost. In this paper, the average fault location time is significantly reduced, and at the same time, the average number of packets issued and the average fault location cost are also significantly reduced. The binary search algorithm described in this paper
improves the operation and maintenance efficiency of the power communication network, and also reduces the cost of fault location.

Reference
[1] Tian Juhong's Fault Diagnosis of Electric Power Communication Network Based on Association Rule Mining: [Master's Degree Thesis] Huazhong University of Science and Technology
[2] Tan Wukun, Yang Qiuhui, Chen Wei. Fault location method of communication network based on Bayesian network [J]. Computer application, 2018, 38(9): 217-220.
[3] Zhang Yu. Application of Fuzzy Neural Network in Mobile Communication Network Fault Diagnosis[D]. Tianjin: Tianjin University of Technology, 2010:22-32.
[4] Zhang Yizhong, Feng Zhensheng, Meng Chen. Research on the Integration of Fuzzy Reasoning and Neural Network in Fault Diagnosis [J]. Systems Engineering and Electronic Technology, 2000, 22(3): 81-83.
[5] Shang Fengjun, Wang Jian. WSN based on end-to-end greedy fault location algorithm [J]. Computer Applied Research, 2015, 32(2): 579-584.
[6] He Qun. Brief Analysis of Deploying End-to-End Network Quality Assessment System by Probe Method [J]. Telecommunication Transmission, 2015, 7(4): 69-72.
[7] Xu Yunbin, Zhao Junfeng, Yang Huifeng, et al. PTN network performance degradation fault location method [J]. Optical network, 2016, 12:27:30.
[8] Zeng Ying, Li Weijian, Chen Yuanyuan, et al. Congestion Avoidance Algorithms for Power Dispatching Data Network Based on Business Priority [J]. Power System Protection and Control, 2014, 42(2): 49-55.
[9] Sun Mengchen, Congwei, Yujiang, et al. Fault location method of relay protection communication system under the background of large data of power network operation and maintenance [J]. Power automation equipment, 2019, 39(4): 141-147.
[10] Bo Lu, and Yan Zhang A Mapping Algorithm for Low-Latency Network slices. Pro-ceedings of the 2017 IEEE International Conference on Information and Automation (ICIA).
[11] Qu Liangdong, He Dengxu, Huang Yong. Bipartite search algorithm based on polynomial root maximum modulus solution [J]. Computer Engineering, 2011, 37(2): 66-68.
[12] Zhu Yanpei, Xing Ningzhe, Ji Yutong, et al. Fault location algorithm for power integrated data network based on in-teractive active detection [J]. Power system automation, 2017, 41(4): 35-40.
[13] Shen Cheng, Liu Huiyong. Design and implementation of large-scale IP network quality measurement system based on hardware probe [J]. Software, 2013, 34(12): 46-50.
[14] Zeng Bin, Zhang Dafang and Zhang Mei. Design and Implementation of Streaming Media Service Performance Measurement Tool Based on Active Testing [J]. Computer Applications, 2008, 28(4): 833-836.
[15] Jiang Kangming, Lin Bin, Qiao Yan. An efficient fault detection and location method based on active detection [J]. Journal of Beijing University of Posts and Telecommunications, 2012, 35(1): 36-40.