WEP Warwick Evans Publishing

International Journal of Mechanical and Electrical Engineering

ISSN: 3005-9615 (Print), ISSN: 3005-7132 (Online) | Volume 2, Number 2, Year 2024
DOI: https://doi.org/10.62051/ijmee.v2n2.02
Journal homepage: https://wepub.org/index.php/IJMEE/index

Research on Communication Simulation of PROFIBUS Multi-master System

Hongxiao Sun, Qiang Zhe, Ziyi Rao, Yuliang Liu, Geng Liang *

College of North China Electric Power University, Beijing, China
* Corresponding Author: Geng Liang

ABSTRACT

As the application background of fieldbus becomes more and more extensive, PROF I BUS contains multiple master stations, and a multi-master system with multiple slave stations emerges at the historic moment. This paper establishes a multi-master communication system model and uses simulation technology to study the relationship between the target token cycle time, token waiting time, and master site address value.

KEYWORDS

Profibus; Fieldbus; Multi-master System.

1. INTRODUCTION

Since the 1980s, with the support of microelectronics technology and computer technology, fieldbus technology has been born. Communication technology in the field of industrial control has gradually developed from traditional decentralized control technology to fieldbus control technology, which realizes two-way, serial, and multi-node digital communication between field devices and is the communication channel between various components in the industrial system.[2] The development of fieldbus has greatly saved the cost of laying cables and installing engineering hardware facilities, and has the advantages of being highly shareable, digital, and intelligent. It can realize convenient observation of on-site signals, which fundamentally improves the reliability of system work and the accuracy of control.

There are many types of fieldbus. Since its birth and continuous development, many companies in the world have launched their own fieldbus technology. However, too many different standards and protocols will bring certain complexity to practice. In order to standardize fieldbus, IEC (International Electrotechnical Commission) and ISA (Instrumentation Society of America) jointly developed the IEC 61158 international standard, which specified 8 types of fieldbus protocol types at the end of 1999. Among them is Profibus.

Profibus mainly completes communication support at different equipment levels in industrial applications. As a medium connecting the controller and the controlled equipment, it plays a key linking role in the entire industrial automation, replacing the role of the process control station in the traditional distributed control system. Under Profibus fieldbus technology, multiple control devices and multiple controlled devices can share one line for data transmission. This technology provides a feasible solution for intelligent operation between field devices. Profibus fieldbus According to different protocol specifications, Profibus fieldbus is divided into Profibus-DP; Profibus-FMS; Profibus-PA. The Profibus protocol structure is based on ISO international standards and uses the open system Internet as a reference model. [1] The model has seven layers, as shown in Figure 1:

User layer	DP Equipment regulations	FMS Equipment regulations	PA Equipment regulations
	Basic functions extended functions		Basic functions extended functions
	DP user interface Direct Data Link Mapper	Application layer interfaces	DP user interface Direct Data Link Mapper
7th floor (Application Layer)		Fieldbus Message Specification (FMS)	
Floors 3-6		Unused	
Layer 2 (Data Link Layer)	Fieldbus information link(FDL)		IEC interface
Tier 1 (Physical Layer)	RS485/LWL		IEC1158-2

Figure 1. PROFIBUS protocol structure

2. PROFIBUS-DP COMMUNICATION ANALYSIS

Profibus-DP uses layer 1, layer 2 and user interface layer, and layers 3 to 7 are unused. This streamlined structure ensures high-speed data transmission. The physical layer adopts the RS-485 standard, which specifies the transmission medium, physical connection and electrical characteristics. The data link layer of PROFIBUS-DP is called Fieldbus Data Link (FDL.), including bus media access control MAC and Fieldbus Link Control (FLC), FLC provides management of service access points and caching of data to the upper layer. FieldBus Management layer 1 and 2(FMA1/2) completes the setting of the pending bus parameters of the second layer and the setting of the first layer parameters. It also completes the error information of these two layers. of upload. The user layer of PROFIBUS-DP includes Direct Data Link Mapper (DDLM), basic functions, extended functions and device profiles of DP. DDLM provides an interface for convenient access to FDL. DP device profile is a specific description of the meaning of user data and stipulates the behavioral characteristics of various application systems and devices. This PROFIBUS protocol, optimized for high-speed transmission of user data, is particularly suitable for communication between programmable controllers and field-level distributed I/O devices.[3]

3. MULTI-MASTER COMMUNICATION SYSTEM MODEL

3.1. System Structure

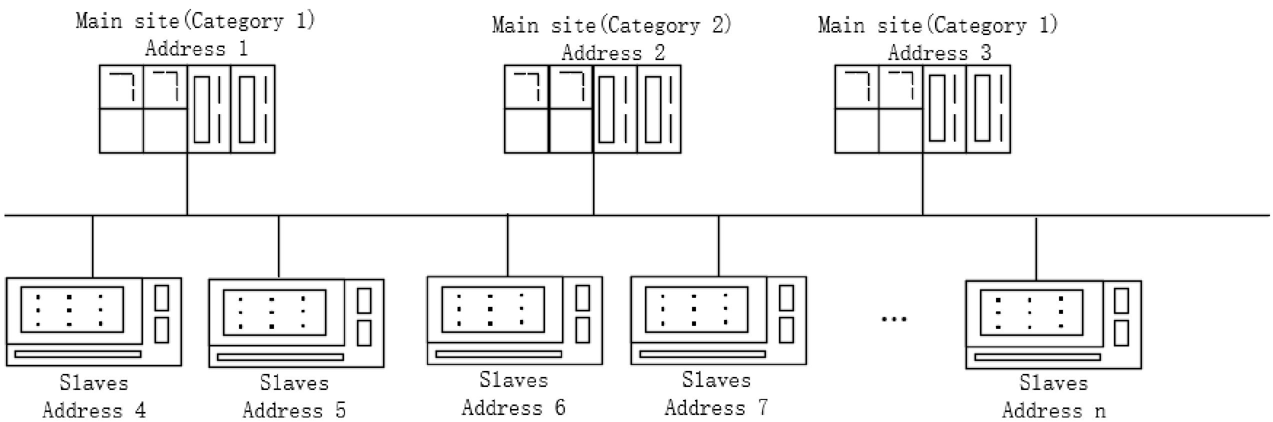

Figure 2. Multi-master system structure

The centralized MAC mechanism of Profibus fieldbus is reflected in the token ring characteristics of multi-master communication. The multi-master structure refers to connecting several master stations on a bus. The master stations use token passing to obtain bus control. The master station that obtains the token exchanges master-slave data with the slave stations it controls. The master station on the bus and the slave stations controlled by each constitute multiple independent master-slave structure subsystems. In a multi-master communication system, the multi-master station completes the encoding of the site address value during configuration, and performs token transmission according to the master station link table on the token ring network. The figure below shows the structure of the multi-master system.[4]

3.2. General Real-time Requirements

The communication traffic on the Profibus network of the multi-master system mainly includes: token passing, data exchange, FDL status request/response, and SDN and SRD low-priority message messages.[5] From the Profibus fieldbus communication delay model, it can be seen that the transmission delay in a measurement and control cycle mainly consists of four parts. When studying the communication mechanism, message queuing delay and data transmission delay are the main transmission delays. Compared with the multi-master system and the single-master system, the main increase in delay is the token transmission delay. When analyzing the communication performance, indicators such as the master site token waiting time are added. There are two main situations regarding token transfer:

(1)Token arrived early:The current value of the token spin time $T_{TH} > 0$, The current station transmits the next message until T_{TH} returns to zero. Once the task is transmitted (including FDL check and retransmission diagnosis), the task is completed, even if the actual token rotation time has exceeded the target token rotation time.

(2)Token late: The current packet processing cycle is too long, or the transmission rate is low. Before the current packet is processed, $T_{TH} = 0$. After processing the current message, immediately release the token and recalculate T_{RR}.

Therefore, in the process of irregular data transmission, tokens will have varying degrees of transmission errors, and the setting of the target token cycle time is very important. Profibus fieldbus is a typical real-time bus. In actual engineering applications, message transmission must meet real-time performance. If the maximum interval for a node to obtain a token is greater than the minimum message transmission period, it means that the node is unable to transmit messages within the minimum message time of the sufficient transmission period, indicating that the real-time performance of the system is not guaranteed. Assume that the minimum message transmission period of a node is $C_{\min}$, The maximum time interval for a node to obtain a token is T_{cmax} , Then one of the conditions for the system to meet real-time performance is (1):

$$T_{\mathrm{cmax}} < C_{\min} \tag{1}$$

When each site communicates and transmits messages, real-time messages have a response validity period. This response validity period is called the deadline for message transmission. In order to improve the efficiency of site message transmission and ensure the transmission of high-priority messages, a single measurement and control cycle should be at least greater than the deadline for high-priority message transmission. Assume that the deadline for high-priority message transmission at the i-th site is H_{i} , Then within a single cycle, the measurement and control polling cycle D_{cycle} At least satisfy the formula(2):

$$D_{\mathrm{cycle}} \geq \sum_{i}^{n} H_i \tag{2}$$

Note: n—number of master stations

In addition, assuming that in a multi-master station system, the conversion time between nodes is m, the conversion time includes token frame response time, message transmission time, etc. In order to ensure the real-time performance of bus transmission, in the master station system The minimum token transmission time period m_c is (3):

$$m_c \geq \sum_{i}^{n} m_i \tag{3}$$

3.3. Communication Performance Analysis

In the master station system, the analysis is mainly based on another key factor in communication delay - the token transmission delay perspective. The communication performance is studied from the aspects of periodic information delay, the relationship between the load of the master station, and the relationship between the master station address value and the token waiting time.

1. Definition of analysis indicators

(1) Node token waiting time: On the Token Ring network, the time from the start of token transmission to the node holding the token. The formula for calculating the token waiting time of node i within one cycle of token polling is as follows(4):

$$t_s = \sum_{1}^{G} t_j \quad \{j \neq i\} \tag{4}$$

(2) Time spent on single node transmission t_i Node token actual holding time. The calculation expression of the transmission time of node i is as shown in (5):

$$t_i = aT_H + bT_L \tag{5}$$

a and b respectively represent the number of high and low priority packets transmitted by node i during data transmission. T_H and T_L are the individual transmission times of high and low priority messages respectively.

3.4. Multi-master System Communication Simulation

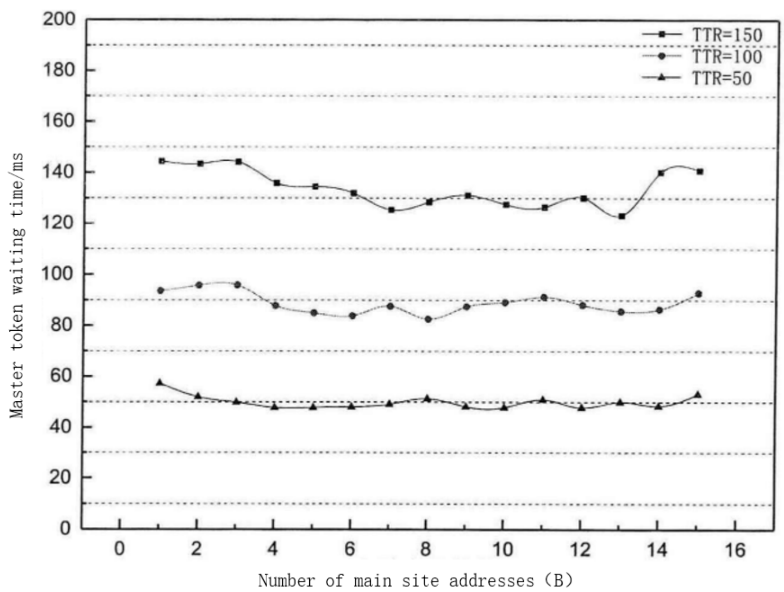

Figure 3. Relationship between main site address value and token waiting time

In order to examine the relationship between the primary site address value, token waiting time, and primary site packet loss rate when all low-priority packets cannot be transmitted. It is set that when the target token cycle time is determined, the token waiting time of each master station is different. Verify the relationship between the two and conduct simulation under the conditions of T_{TR} of 50ms, 100ms, and 150ms respectively, the simulation results are shown in Figure 3.

Set the number of master stations B=15, $T_H = 0.5$ms, $T_L = 1$ms, polling cycle L=10, set the high priority message transmission cycle within the range of [0,2], and set the low priority message number message transmission cycle Set the random distribution within the range of [1,10], observe the relationship between T_{TR} and t_s and draw the curve graph as shown in Figure 4:

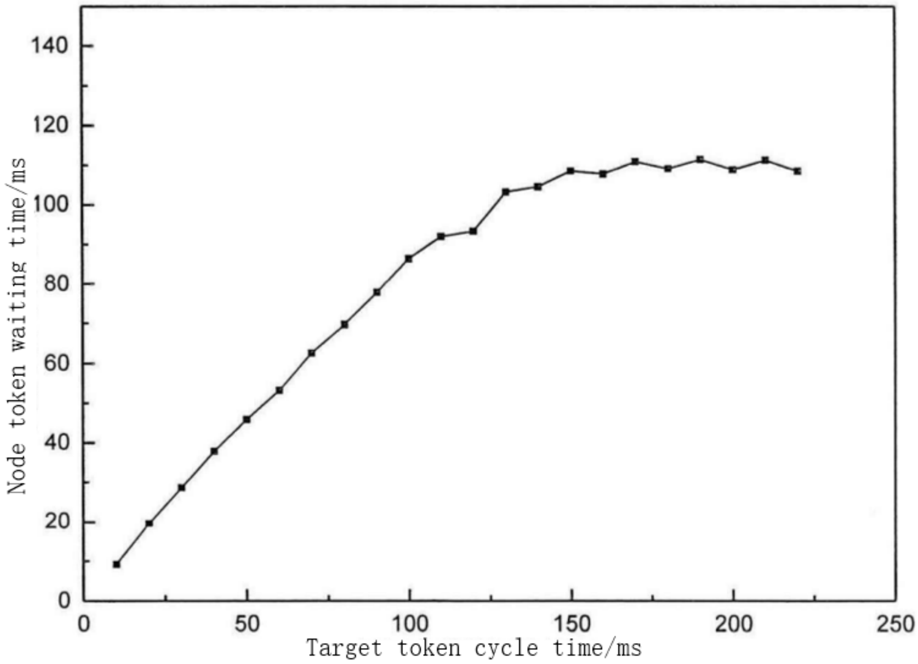

Figure 4. Relationship between target token circulation time and token waiting time

4. SUMMARY

In the simulation of the multi-master communication system, the token transmission delay is mainly studied around the transmission delay. Obtained the setting of the target token cycle time and the relationship between the target token cycle time and the token waiting time, as well as the relationship between the main site address value and the token waiting time. Through the simulation results, it can be concluded that the token waiting time of stations with smaller and larger main station address values is longer than that of stations with address values in the middle. This feature is used when the target token rotation time is large, that is, each station This is more obvious when more low-priority packets can be transmitted. As the target token cycle time increases, the single node token waiting time gradually increases. When the target token rotation time increases to a certain extent, the node token waiting time remains unchanged within a small range.

REFERENCES

[1] An Xin. Simulation study on Profibus Fieldbus communication performance[D].North China Electric Power University (BEIJING),2020.DOI:10.27140/d.cnki.ghbbu.2020.000201.

[2] Vitturi S. DP-Ethernet: the Profibus DP protocol implemented on Ethernet[J]. Computer communications, 2003, 26(10): 1095-1104.

[3] Fang He and Kai Guo. Modeling and simulation of PROFIBUS-DP network controlsystem. 2008 IEEE International Conference on Automation and Logistics,Qingdao,2008, pp.1141-1146.

[4] Willig,A. Polling-based MAC protocols for improving real-time performance in awireless PROFIBUS[J]. IEEE Transactions on Industrial Electronics，2003,50(4):806-817.

[5] H. Kaghazchi, Hongxin Li and M.Ulrich. Influence of Token Rotation Time in multimaster PROFIBUS networks. 2008 IEEE International Workshop on FactoryCommunication Systems, Dresden, 2008, pp. 189-197.